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WAR DEPARTMENT

TECHNICAL MANUAL

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AIRCRAFT PROPELLERS

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No. 1-412

WAR DEPARTMENT,
WASHINGTON, October 21, 1940.

AIRCRAFT PROPELLERS

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Prepared under direction of the
Chief of the Air Corps

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SECTION I

GENERAL

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1. General.—a. Power to drive the airplane through the air is furnished by the engine, the brake horsepower of which is transformed into thrust by the propeller. The propeller may be described as a twisted airfoil of irregular plan form. In order to analyze the blade element, each blade is divided into 6-inch sections and each section is set at the proper angle to the relative air (fig. 1). The sections near the tip of the propeller travel at a higher peripheral speed than those near the hub, consequently the blade angles become less as the tip is approached. The sections from 12 to 18 inches from the hub are thick in order to give strength to the propeller, and as a result, deliver little or no thrust. In general, each section is so designed and set at such an angle that when the propeller is being operated at a given rotative and forward speed, the best efficiency of each section will be obtained.

b. The angle at which each section meets the air in flight is much less than the actual blade angle of each section. This is due to the fact that the propeller is moving forward as well as rotating (fig. 2). The section G which is R distance from the hub, moves in one revolution $2\pi R$ distance and in N revolutions it moves $2\pi RN$ distance. This distance is shown graphically by the line ac . While the propeller is revolving N times, it is also moving forward a distance represented by bc . The blade angle of this section is the angle D , while the angle at which the section meets the air, or its angle of attack, is represented by the angle E . Under normal flight conditions this is usually about 2° , but in a power dive it is possible for the airplane to obtain a speed, due to acceleration by the force of gravity, which is greater than the propeller tends to produce. When this occurs, the propeller is actually holding the airplane back and the condition shown in figure 3 is approached. In this case the angle of attack E of the propeller section G is less than zero and no thrust is produced. In the opposite, as in a steep climb with the forward speed reduced but the rotative speed held constant, the angle of attack becomes greater until the efficiency of the propeller is very low (fig. 3②).

c. Fixed pitch propellers are designed to have best efficiency at one rotative and forward speed. In other words, they are designed to fit a set condition of both airplane and engine speeds and any change in these conditions results in lowering the efficiency. Since the advent of the controllable propeller, on which the blade angle may be set or automatically changed to a new set of conditions, this lowering of efficiency had been greatly reduced.

2. **Terms.**—Some of the principal propeller terms used throughout this manual are as follows:

a. *Blade angle.*—The angle between the chord of a section of a propeller blade and a plane perpendicular to the axis of rotation. The blade angles for different airplane and engine combinations are specified in Air Corps Technical Orders. Deviation from these settings as much as 1° above to $\frac{1}{2}^\circ$ below may be authorized. One degree change in blade angle will affect the engine r. p. m. between 70 to 100 r. p. m.; on geared engines this will vary with the gear ratio.

b. *Blade back.*—The cambered or curved side of a propeller blade, similar to the upper surface of an airfoil section.

c. *Blade face.*—The flat side of a propeller blade, similar to the lower surface of an airfoil section.

d. *Blade root.*—The portion of the blade located in the hub.

e. Effective pitch.—The actual distance a propeller blade moves forward in one revolution in the air. Although this may be given in feet, it is usually computed in percent.

f. Feathering.—The term “feathering” designates the operation of rotating propeller blades beyond the highest angle required in normal flying to an approximate in line of flight position which prevents the propeller from “windmilling” in flight with the engine power completely off.

g. Geometrical pitch.—The distance a propeller blade would move forward in a solid medium in one revolution. This may be calculated by multiplying the tangent of the blade angle by $2\pi r$, r being the radius of the blade station at which it is computed.

h. Slip.—The difference between effective pitch and geometrical pitch. This is usually expressed in percent.

i. Track.—The relationship of like points on all blades of a propeller, normally along the blade center lines, to a plane perpendicular to the axis of rotation.

3. Types.—There are three general types of propellers: fixed pitch, adjustable pitch, and controllable pitch.

a. The fixed pitch type is manufactured in one piece; no adjustment of the pitch can be made. It may be of wood or metal and its use at this time is limited to engines of relatively low power.

b. The adjustable pitch type has a split hub which permits the adjustment of the blades on the ground. The propeller is removed from the engine when this adjustment is made. Two or more blades may be used; they are usually of metal but may also be of other materials.

c. The controllable pitch type permits adjustment of the blade angle during operation of the engine in the air or on the ground. Two or more blades may be used. The mechanism for controlling the blade angle may be mechanical, hydraulic, or electrical.

4. Stresses and vibration.—*a.* There are three general types of stresses induced in a propeller: bending, tensile, and torsional.

(1) The bending stresses which are induced by the thrust forces that tend to bend the blade forward are the most pronounced. Other bending stresses caused by air drag on the blade are negligible.

(2) The tensile stresses are caused by centrifugal force.

(3) The torsional stresses are due to the forces which tend to twist the blade.

b. Fatigue due to vibration is the greatest cause of propeller failures. Vibrations can be set up by certain irregularities of air flow such as might be caused by a coolant radiator placed too close to the plane of

propeller rotation. The main cause of propeller vibration is the engine power impulses. Vibration, if continued at the natural frequency of the propeller, will cause failure in a few hours' operation. Each engine has a critical range of operation for each type of propeller with which it is combined. Continued engine operation in this critical range must be avoided. Dynamic balancing of crankshafts and flexible drive couplings between the engine and propeller have greatly reduced propeller vibration and subsequent failures due to fatigue.

5. Advantages of the controllable propeller.—*a.* The primary purpose of a controllable propeller is to permit the engine to develop full-rated power; second, to permit the propeller blades to operate at the most advantageous blade angle; and third, to permit readjustment of the blade angle to the particular power and altitude conditions. Summarizing the utility of the controllable propeller, a gain in performance is always obtainable when operating at any flight condition other than the one for which the blade angle of a noncontrollable propeller is set.

b. Where high efficiency of the engine and airplane is desired, the controllable propeller is a necessity. In the case of larger airplanes at take-off using noncontrollable propellers, the length of run would be great, and as long as the distance of take-off is limited to the extent of the airdrome, the controllable propeller is invaluable. The advantages in climb and cruising are just as pronounced.

c. Noncontrollable or ground adjustable propellers are designed and set so that the engine turns at its rated speed in normal level flight. When the propeller is designed and used in this way, its characteristics are such that it holds the engine to about 80 percent of its normal r. p. m. and consequently about 80 percent of its normal power output during take-off. Thus an engine normally rated at 800 hp. would develop only about 640 hp. at the time of take-off. During climb, this same propeller will hold the engine about 85 percent to 90 percent of its rated speed so that the horsepower output of the engine would be around 720. This loss of engine power is avoided by the use of the controllable propeller, since the blades can be adjusted to as low a pitch as is necessary to allow the engine to develop its full-rated horsepower.

d. In general, engines have a certain maximum safe speed for cruising and a certain safe manifold pressure at that speed of rotation. However, at high altitudes, the lower density of the air causes the propeller to allow the engine to turn at a higher r. p. m. than at lower altitudes. In a controllable propeller, the pitch may be adjusted to a higher angle to compensate for this difference in air density.

e. Some types of controllable propellers incorporate a feathering feature. In the feathered position they act as brakes to stop the engine rotation and at the same time offer the least possible drag on the airplane. The ability to stop an engine from rotating in case of an engine failure on multiengine airplanes is, from the safety standpoint, the greatest asset of the feathering feature. In addition, flight tests with bimotored airplanes with propellers which can be feathered have shown a definite improvement in all phases of single-engine performance (fig. 4).

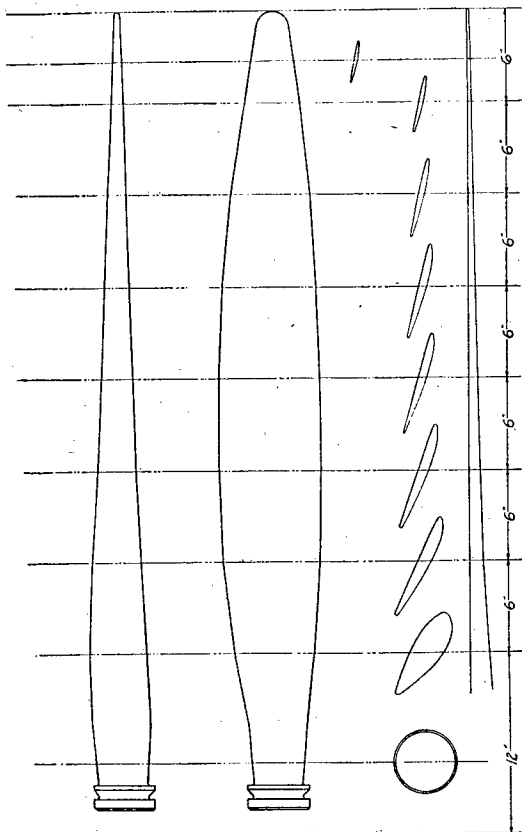


FIGURE 1.—Typical propeller blade.

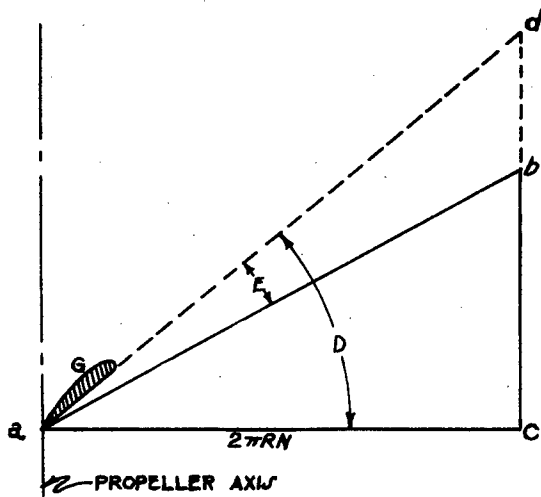


FIGURE 2.—Blade angle and angle of attack in normal flight.

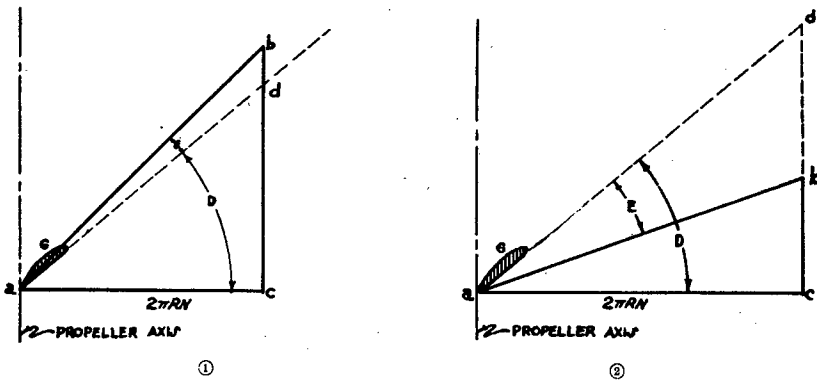


FIGURE 3.—Blade angle and angle of attack in a dive and in a steep climb.

AIRCRAFT PROPELLERS

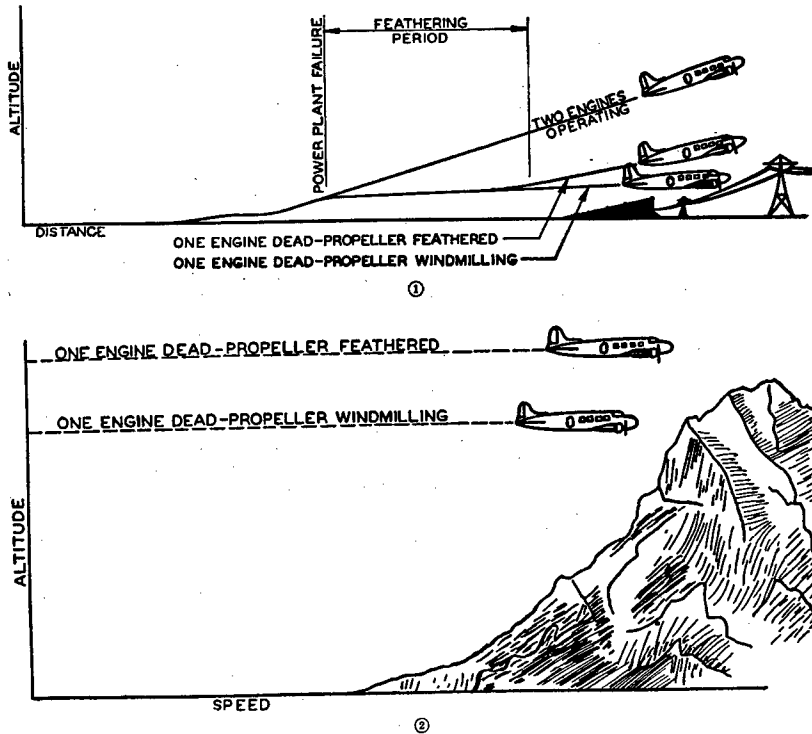


FIGURE 4.—Comparative performance with propeller feathered on dead engine.

SECTION II

GROUND ADJUSTABLE PROPELLER

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6. General.—The ground adjustable propeller is noncontrollable and, as the name implies, can be adjusted only while on the ground. The propeller consists of two or more blades and a hub. Inasmuch as the blade angle is not controllable, it is set at the time of assembly for an angle that is fairly efficient for all service conditions. This angle is determined by flight tests and is specified by Air Corps Technical Orders. Since the advent of the controllable propeller, the use of this type of propeller is confined almost entirely to primary training type of airplanes.

7. Description of ground adjustable propeller having aluminum alloy blades.—*a.* The blades are of aluminum alloy and are of conventional design. Shoulders are machined on the blade shank as means of securely attaching them to the hub to take up the centrifugal force on the blades. A concentrically located hole is drilled in the root end of the blade to aid in balancing the propeller.

b. The hub is of chrome vanadium steel, cadmium plated. It is machined in halves with recesses to accommodate the blade shoulders. The blades are retained in the hub by the blade shoulders seating in the hub recesses aided by the friction of the two halves being drawn together by a ring clamp located at each end of the hub.

c. This propeller uses a spacer behind the rear cone to properly locate the propeller on the shaft and to prevent interference with the engine cowling. The retaining nut, front cone, snap ring, and rear cone are standard parts. Instruction pertaining to the inspection and inspection maintenance of these parts is explained in section IX. A typical ground adjustable propeller is shown in figure 5.

8. Description of ground adjustable propeller having solid steel blades.—*a.* Some types of ground adjustable propellers have solid steel blades and a different means of retaining the blades in the hub. But like the ground adjustable propeller having aluminum alloy blades, their use is confined to the primary training type of airplane.

b. The sections are thin and the shank and root end of the blade small in comparison to the aluminum alloy blade. A change in the airfoil section from the conventional Clark Y or R. A. F. 6 to a radically different section has been made in this type of propeller. A shoulder has been machined on the butt end of the blade which, when assembled in the recess of the hub, resists centrifugal force on the blade during operation. The weight of the blade is approximately that of the aluminum alloy blade.

c. The hub is of the split type and is manufactured from high-strength steel. Replacing the ring clamps as used on the conventional split type hub are four bolts which hold the halves together. A recess is machined in each blade socket to accommodate the shoulder of the blade. Internal threads are cut in the end of each hub blade bore for a split type nut which, when screwed into the hub, helps prevent any movement of the blade. The blade is also held from turning by two cup point set screws which are safetied together.

9. Installation and removal.—*a.* When installing the ground adjustable propeller, the applicable provisions of section IX are complied with in addition to the following:

(1) In the order given, assemble rear cone spacer and rear cone on crankshaft.

(2) Install propeller on crankshaft. Care should be exercised to prevent damage to the threads of the crankshaft. If difficulty is encountered when installing the propeller, check the splines of the hub for alinement. At no time should force be used to install the propeller on the crankshaft.

(3) Assemble the two halves of front cone on flange of retaining nut and screw nut on shaft. The tightening is accomplished by using a bar approximately 4 feet in length. One man of average weight (175 pounds) can tighten the retaining nut sufficiently without additional leverage or the use of a hammer.

(4) Insert snap ring.

(5) Secure retaining nut by installing a clevis pin of correct size in alined holes of retaining nut and crankshaft. The pin is inserted from the center of the crankshaft.

(6) Safety with cotter pin.

b. The procedure of removing a ground adjustable propeller from the crankshaft is as follows:

(1) Remove cotter and clevis pin.

(2) Unscrew retaining nut. This will pull the propeller off the shaft. If difficulty is encountered in removing the propeller, remove snap ring, retaining nut, and front cone and thoroughly clean threaded portion of nut and shaft. Lubricate retaining nut and shaft with clean engine oil and thread lubricant, reassemble, and apply sufficient force to unscrew the nut. Do not damage threads of shaft when sliding propeller from shaft.

10. Inspection and inspection maintenance.—*a.* A visual inspection is made of the retaining nut lock pin, ring clamp nuts, and hinge pins as to condition and position of the cotter pins. All worn or damaged pins are replaced with serviceable parts. Any interference between the ring clamp bolts and nuts and engine cowling is corrected before flight, but under no circumstances will the position of the ring clamps be changed after the propeller has been balanced.

b. A physical check for looseness of the retaining nut is made as follows:

(1) Remove retaining nut lock pin.

(2) Insert 4-foot bar into retaining nut. One man weighing approximately 175 pounds pulling on the end of the bar is sufficient to check retaining nut for looseness. The force is applied steadily, avoiding jerking on the bar. Do not use additional leverage or force to make the check.

(3) Replace retaining nut lock pin and safety with cotter pin.

c. At the specified periodic inspection, the ring clamps are checked for looseness as follows:

(1) Remove cotter pin from ring clamp nut.

(2) Insert wrench with a leverage not to exceed 12 inches on the nut, and with a normal pull, check nut for looseness.

(3) Safety nut with cotter pin.

(4) Repeat the operations on the other ring clamps.

d. *Maintenance problems.*—Listed below are a number of maintenance problems with which the airplane mechanic may be confronted. They are of such a nature that the airplane mechanic can make the necessary checks and corrections.

(1) Retaining nut has been tightened but propeller remains loose on shaft. The probable cause for this condition is either the front or rear cones "bottoming." In case the front cone is bottoming, it is corrected by the addition of a locally manufactured spacer which is placed behind the rear cone. In event the rear cone is bottoming, $\frac{1}{16}$ inch is cut off the apex of the cone or it is replaced with a new rear cone.

(2) Trouble is encountered when installing propeller on crankshaft; that is, the rear half of the hub will go on the shaft while the front half will not. Splines in the halves of the hub being out of alinement will cause this condition. Loosen ring clamps slightly and tap hub with a rawhide mallet. This allows the front half of the hub to properly aline itself in relation to the shaft and will correct the condition. Care must be taken not to disturb the blade angle during this operation.

(3) Excessive vibration in the propeller may be one or more of several probable causes. The airplane mechanic should check propeller blade for looseness in the hub, the hub for looseness on the shaft, blade angle settings and propeller for track. If the above checks are found correct or within the specified tolerance, the propeller is removed from the shaft and checked for balance. If this fails to correct the condition, there is little or nothing remaining for the airplane mechanic to do except make a report to the proper authorities.

(4) Additional information on inspection, maintenance, and repair is found in Section IX.

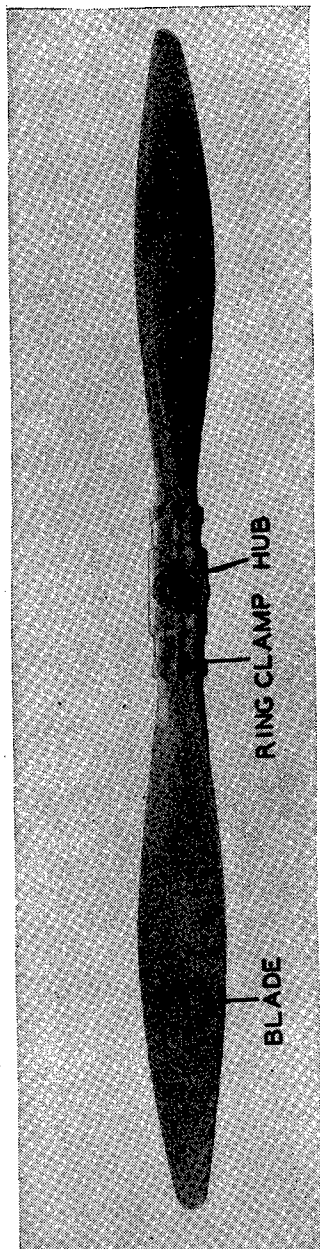


FIGURE 3.—Ground adjustable propeller.

SECTION III

LYCOMING-SMITH CONTROLLABLE PROPELLER

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11. Principle of operation.—The Lycoming-Smith controllable propeller (fig. 6) accomplishes a change in blade angle mechanically from the rotation of the propeller shaft. The blades are turned about their longitudinal axis by engaging and disengaging a series of gears in the hub with a stationary worm mounted on the engine. The propeller gears operate only during a change in the blade angle. The high gear ratio affords a sufficiently slow movement of the blades to permit the pilot to select the particular blade angle desired and to make the gears irreversible. The propeller gear mechanism is engaged and disengaged by means of an electric solenoid control. A pitch indicator mounted on the engine instrument panel, indicates the angle of the propeller at all times.

12. Description.—The description of the major assemblies is of a general nature. No attempt is made to describe all of the component parts making up these assemblies nor should the description be construed as instructions for the assembly of the propeller.

a. The hub is a one-piece chrome vanadium steel forging. The blade assemblies are retained in the hub by blade nuts screwed into the end of the blade barrels of the hub and locked to the hub with serrated lock plates. Buttress threads are used in the hub and on the blade nut to take the centrifugal load of the blades. The gear mechanism of the propeller is encased in a gear housing which is assembled over dowels in the rear cavity of the hub and held in position by three bolts.

b. The blades are made of chrome vanadium steel and are of hollow construction. The exterior of the blade is chrome plated to provide a protective coating. This blade is adapted to the propeller design, inasmuch as the blade bearings can be located on the blade shank and threads can be machined directly on the blade shank. To reduce the bending stresses originating from the thrust loads, the blades are tilted forward $1\frac{1}{2}^{\circ}$. A counterbalance is used on each blade to neutralize the twisting moment, which is inherently true of all propeller blades.

c. The blades are secured in the hub by a series of ball bearings so arranged and held on the blade shank that the moments and loads are evenly distributed to each bearing. As the centrifugal load on the blades is applied by the rotation of the propeller, the outer races of the blade bearings tend to expand in the hub and the inner races contract around the blade shank to hold the blade assembly rigidly in the hub. A blade end bearing locates the blade radially. A slight preloading of the main blade bearings against the end bearing is provided, insuring a rigid blade assembly at low engine speeds.

d. When the control worm rotates the blade stop gear (fig. 7), the gear rotates the tube on which the gear is mounted through a ratchet clutch on one end. A stationary threaded shaft is mounted inside the tube, carrying two adjusting nuts which are keyed to the tube. When the tube rotates, the nuts rotate and travel together along the stationary shaft until one nut pushes the driving clutch out of engagement with the blade stop gear. The gear continues to turn, but the clutch, tube, and worms mounted on the tube stop rotating. Reversal of the control reverses the direction of rotation of the blade stop gear and drives the tube through a second ratchet clutch of the opposite hand on the other end of the gear. The nuts on the stationary shaft travel together toward the second clutch, eventually pushing it out of engagement and stopping rotation of the tube and worms. By adjusting the distance between outer faces of the adjusting nuts on the blade stop shaft, the rotation of the blade stop mechanism may be limited to a definite number of revolutions before the clutches disengage the blade stop gear. Thus a means is provided to limit the operation of the propeller gear train within definite blade angle limiting stops.

e. A control housing adapter (fig. 8), which locates a stationary control worm concentric with the propeller shaft, is mounted on the engine crankcase front cover. The stationary control worm has two threads on its outer circumference; a rear or right-hand worm thread, and front or left-hand worm thread. When the stationary control worm is in its neutral position, the worm threads are out of mesh with the propeller hub gears. By shifting the control worm forward or rearward, one or the other of the worm threads is engaged with the teeth of the blade stop gear in the propeller hub. The blade stop gear is rotated one tooth space by the stationary control worm with each revolution of the propeller hub. The rotation of the blade stop gear is transmitted through the blade stop worms to the three blade stop worm shafts which mesh with the blade gears attached to the

ends of the blades. The movement of the blade gear nut turns the blades in their socket in the hub.

f. The nut on the end of the blade shank has gear teeth cut around its circumference to engage the blade worm shaft in the final stage of the propeller gear train. The blade gear is screwed directly over the buttress threads on the blade shank and is locked securely by a serrated lock plate doweled and screwed to the blade end.

g. To overcome slight variations in the weight of the blades, balance weights are installed in the gear housing. The position of these weights is not disturbed unless it is intended to balance the propeller.

13. Installation and removal.—*a.* The instructions for installing propellers as outlined in section IX are followed when installing this type of propeller.

(1) In order to obtain the proper location of the blade stop gear in the propeller hub with respect to the control housing worm in the control housing adapter, four rear cone shims are furnished with each propeller. The shims vary in thickness from $\frac{1}{32}$ inch to $\frac{3}{32}$ inch by 64ths. Place the thickest shim over propeller shaft sliding it back against thrust bearing nut. Assemble bronze rear cone, sliding cone back against the shim. Install crankshaft thread guard on propeller shaft. The purpose of this tool is to protect the threads on the propeller shaft and to prevent the threads from scraping any plating from the inside of hub splines.

(2) The propeller, from which the retaining nut, front cone, and snap ring have been removed, is raised to the proper height and pushed back over the thread guard and over the splines of the crankshaft. The thread guard is then removed. If facilities are available, the tail of the airplane is raised to a level position before the propeller is installed or removed. Place the halves of front cone on flange of retaining nut and screw on crankshaft. Firmly tighten nut in place by means of a bar approximately 5 feet in length, passed through the nut so as to extend equally on each side. Two men of average weight should use the bar, one pushing upward, the other pulling downward, and applying an equal force on each end of the bar. For final tightening of the retaining nut, use a 2-pound lead hammer applying about two or three raps on the downward or pulling side of the bar close to the nut. Install snap ring hub nut lock, spacer, and screw. Tighten screw and safety to the hub. The model P-432-2 propeller hub retaining nut is locked to the hub with lock and cotter pin. The head of the lock pin is on the inside of the propeller hub nut.

(3) A check is made as to the location of the propeller hub with respect to the adapter assembly. This is done on the model P-5315

propeller installation by inserting a thickness gage in the clearance between the propeller locating pin (on the rear of the propeller) and the front face of the propeller control housing. This installation clearance is $\frac{3}{16}$ inch, plus or minus 0.008 inch. The installation clearance for the model P-432-2 propeller is 0.030 inch plus or minus 0.008 inch as measured from the rear face of the hub cover to the front face of the control adapter. If the clearance as measured above is greater or less than specified, the propeller is removed and the rear cone shim replaced with one of such thickness as will provide an installation clearance within the tolerance.

(4) Following installation of the propeller, control, and pitch indicator, the following tests are made: before operating for the first time, turn propeller over by hand in direction of engine rotation to insure clearance of all engine and airplane parts. Check all wiring from switches to propeller. Check stops in pitch indicator to determine if they are set for the minimum and maximum angle of propeller.

b. To remove propeller, remove hub nut lock screw, spacer, and lock from flange in front of the hub. Unscrew hub nut an amount sufficient to loosen hub from rear cone. Before removing propeller from crankshaft, remove snap ring from hub and unscrew hub nut further so as to remove front cone and nut. Screw crankshaft thread guard on propeller shaft and then remove propeller.

14. Lubrication.—*a.* The hub of the Lycoming-Smith controllable propeller is to be full of grease during all propeller operations. A grease filler connection is furnished for use in lubrication. The hub of the propeller is lubricated as follows:

(1) Remove plug from one of the cover plates on side of hub and assemble grease connection.

(2) Remove screw from venthole opposite cover plates.

(3) Rotate propeller so venthole is upward.

(4) With clean grease gun, completely fill hub with grease. When filled, grease will overflow from venthole.

(5) Remove grease connection from side of hub and replace plug and screw. Safety screw to hub cover screws.

b. If propeller hub has been disassembled and filled with grease prior to reinstallation, the grease will pack along the blade bearings during the first few minutes of operation. It is necessary to refill hub after 5 minutes of ground operation. Before installing propeller hub on shaft, care must be taken to clear grease from annual opening in hub cover plate in order to permit entrance of control worm.

15. Propeller controls.—*a. General.*—Rapid engagement and disengagement of the stationary control worm with propeller hub

gears is accomplished by means of an electric solenoid control unit (fig. 9) which is assembled on the control adapter on the engine. The control is operated by relays from switches in the cockpit. These are momentary type switches, and by the correct manipulation of the switch, the pilot can obtain any angle in a predetermined range. The solenoid control assembly is a 12-volt, 2-wire radio shielded unit, consisting of a housing and cap assembly in which are incorporated two solenoids. The two solenoid plungers are assembled on the ends of a rack which meshes with the lower of two gear segments splined to a supporting shaft. An adjustable rack support bearing mounted on the housing base prevents distortion of the plunger and rack assembly and reduces friction on the solenoid plungers. The upper gear segments mesh with the top rack which is riveted to both the bumper plate assembly and operating rod. The bumper plate actuates the pitch indicator contact switches mounted on the housing. A slot provided in the top rack engages with the shift arm in the propeller control housing. The cycle of operation is as follows: Upon closing the propeller control switch in the cockpit, one of the control relays closes thereby energizing one coil in the solenoid control unit. The solenoid actuates the solenoid plunger and rack, longitudinal motion being transmitted by means of gear segments to the operating rod and top rack which engages the control housing shift arm. Operation of the control housing shift arm rotates the shift ring and control worm through a small angle. This movement of the control worm causes the blade stop mechanism to rotate, which in turn will make the gear train operative through a series of gears to the blades which turn the blades in the hub. When the desired blade angle has been reached, the propeller control switch is returned to the neutral position. The springs provided at either end of the operating rod return the control housing shift arm to the neutral position, thereby disengaging the propeller shifting mechanism in the propeller and opening the pitch indicator circuit. The operating rod is held in the neutral position by a ball and spring device when the propeller control is not in use.

b. Installation.—(1) Mount control adapter on front crankcase cover over bolts projecting through the cover so that shift arm is in the middle of its travel and extends vertically downward. Assemble washers and nuts on bolts and tighten evenly. Lock nuts together with safety wire. See that adapter assembly operates freely and without binding after installation by moving shift arm to its limit of travel. Apply clean engine oil to felt seal in groove in adapter.

(2) Remove control housing cap from propeller control and mount cap in groove on upper half of control adapter so that the narrow side section extends to the rear. Oscillate cap to insure that head of pin in control adapter fits into hole in cap. Adjust shift arm in middle of its travel so that it points straight downward. Hold cap in place on control adapter and assemble propeller control housing assembly with flat face forward in groove on lower half of control adapter. When sliding studs through holes in the cap, be sure that shift arm in adapter assembly enters into slot in operating rod of control assembly. Assemble nuts and washers on studs in control housing and tighten evenly. Safety nuts with cotter pins. Install supports. Use standard Air Corps drawing to determine the location of supports.

c. Propeller pitch indicator.—(1) This instrument indicates at all times the exact blade angle at which the propeller is operating. In principle, the indicator consists of a small gear mechanism having exactly the same ratio as the propeller gearing and driven from the gun synchronizer drive connection in the engine. An electrically-operated clutch in the pitch indicator engages the indicator gear mechanism simultaneously with the gear mechanism in the propeller, thus causing the indicator hand to follow the movement of the blades throughout their range of blade angles.

(2) Before installing pitch indicator assembly, check model designation as being correct for the particular propeller being installed. Also see that pitch indicator dial hand stops are set for maximum and minimum blade angles stamped on propeller blades. These stops on the pitch indicator are adjusted by removing the dial snap ring and glass from the instrument. Attach one end of a standard flexible drive shaft assembly to the pitch indicator drive assembly mounted on the gun synchronizer pad with gasket and cap screws. Attach the other end of flexible drive shaft assembly to fitting on reduction unit which is mounted on pitch indicator assembly. The installation of electrical lines and conduit for the pitch indicator are made in accordance with a standard wiring diagram for the particular airplane on which it is to be installed.

16. Operation.—*a.* Start engine and open throttle until approximately 800 r. p. m. are obtained and then allow engine to warm up. To insure low pitch (high r. p. m.), open throttle to 1,000 r. p. m. and manually operate propeller control to low pitch (high r. p. m.) until there is no further increase of r. p. m. indicated on the tachometer. Do not operate propeller control while engine is operating at less than 1,000 r. p. m.

b. For take-off, climb, and cruising, operate propeller control manually to increase or decrease the r. p. m. in accordance with operation instructions for the particular engine airplane combination to obtain best operating r. p. m. for flight conditions.

c. When gliding in to land, manually operate propeller control to low pitch (high r. p. m.). This position allows maximum r. p. m. to be developed in case of an emergency.

17. Inspection and inspection maintenance.—*a.* As part of the daily inspection, the range of operation of the propeller is checked as follows:

(1) With the engine warmed up to operating temperature, set throttle to give 1,000 r. p. m.

(2) Move propeller control switch to the "decrease r. p. m." position and hold it until no further decrease in r. p. m. is noted on the tachometer. Check pitch indicator to see that it indicates the maximum angle setting of propeller.

(3) Move propeller control to the "increased r. p. m." position and hold it until no further increase in r. p. m. is noted by the tachometer. Check pitch indicator to see that it indicates minimum angle setting of propeller.

(4) Check each propeller as outlined above.

b. The control switches, relay box, and pitch indicator are inspected for loose screws, bolts, pins, etc.; all conduit, wire, and electrical terminals are inspected for corrosion, accumulation of dirt and oil, and looseness of terminals. All defects are corrected before flight.

c. The procedure below is followed when checking retaining nut for looseness.

(1) Remove locking device.

(2) Insert a 5-foot bar evenly spaced into retaining nut, one man weighing approximately 175 pounds pulling on the end of the bar while another pushes up on the opposite end. The force is applied steadily with no sudden jerks. Final tightening is accomplished by striking the bar next to retaining nut two blows with a 2-pound hammer.

(3) Check installation clearance.

(4) Safety retaining nut.

d. Maintenance problems.—The maintenance problems listed below are most likely to occur during normal operation.

(1) Grease leaking from around rear of hub is a common occurrence and is caused by the felt seal in the control adapter being worn. To correct this requires the removal of the propeller and replacement of the gasket.

(2) Failure of the pitch indicator to register the blade angle may be caused by improper connections or a broken shaft. All wiring should be checked in accordance with Air Corps Technical Orders and the shaft inspected for loose connections and condition.

(3) Failure of the propeller to change pitch will normally be noticed at the preflight inspection. To correct this, remove front plate from solenoid housing and move propeller switch in cockpit

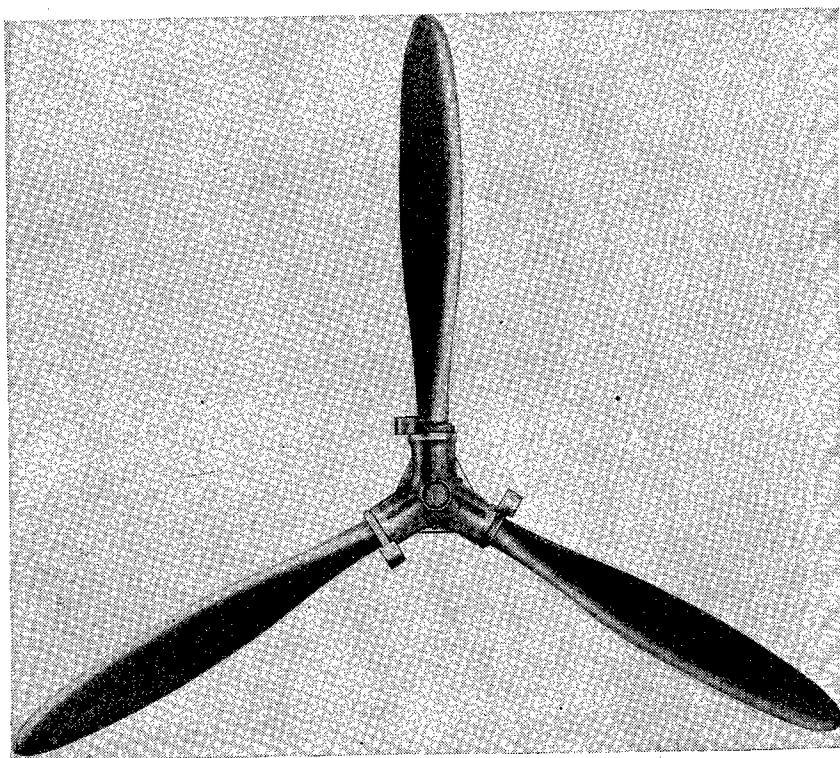


FIGURE 6.—Lycoming-Smith controllable propeller.

to either "increased" or "decreased" r. p. m. position. This closes the circuit to the solenoid, which should operate the rack; if not, check all wiring for proper connections. Check relay for condition of wiring and connections. If these checks prove that all electrical connections are in good condition, the trouble may be in the control adapter or propeller. In either case, the service of a trained propeller mechanic should be secured to correct them.

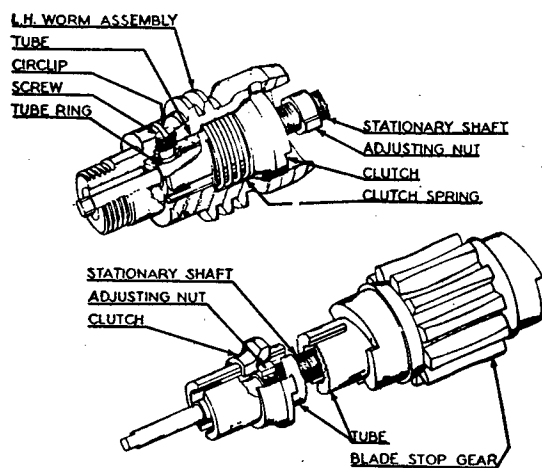


FIGURE 7.—Blade stop mechanism (schematic view).

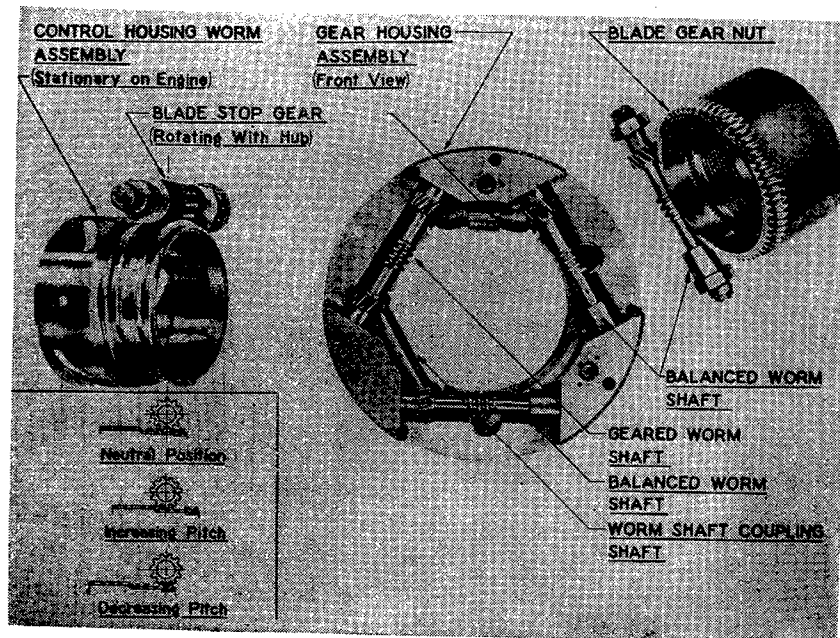


FIGURE 8.—Gear train.

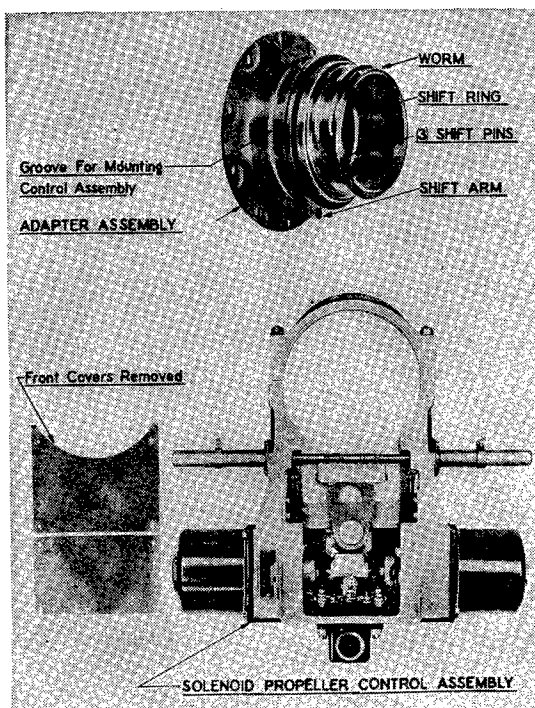


FIGURE 9.—Propeller controls.

SECTION IV

CURTISS CONTROLLABLE PROPELLER

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18. Models and principle of operation.—a. Models.

Design number	Manufacturers' model	Manufacturers' type	Application
55012	Number C-4315-S	Hollow steel.....	PB-2A
55003-D-2	C-532-D	Aluminum alloy.....	A-18
55014-B-4	C-5315-S	Hollow steel.....	P-36A
55014-B-6	C-5315-S	Hollow steel.....	P-37

The code used to designate these various propeller models may be interpreted as follows:

- (1) The prefix letter "C" indicates Curtiss as the manufacturer.
- (2) The first digit indicates the S. A. E. standard shaft upon which the hub will fit. For example, the digit "4" indicates a number 40 shaft size and "5" indicates a number 50 shaft size.
- (3) The second digit indicates the number of blades of the propeller.
- (4) The third or third and fourth digits indicate the blade shank size; for example, the digit "2" indicates a standard No. 2 blade shank or "15" indicates a standard No. 1½ blade shank.
- (5) The suffix letter "S" or "D" indicates whether the blades are made of steel or aluminum alloy.

b. Principle of operation.—The Curtiss controllable propeller (fig. 10) is operated electrically from the airplane power supply. The electrical energy for changing the propeller blade angle passes through brushes, mounted in a housing attached to the engine nose, to slip rings mounted in the rear boss of the propeller hub, and thence to the pitch changing motor through connector leads passing through the hub. The electric pitch changing motor controls the angle of blade setting through a two-stage planetary gear speed reducer, which drives a single bevel gear. This gear meshes with a mating bevel gear attached to the shank of each blade. The two motor fields provide a means for opposite directions of rotation of the motor, thereby providing for an increase or decrease in the angle of the blades. The governor is designed to open and close two different electrical circuits. One circuit contains the field which causes right-hand rotation of the motor, and the other contains the field causing left-hand rotation of the motor. Any variation of engine speed will cause the contact points of the governor to make contact in either the increase or decrease pitch circuits, depending on the position of the flyballs in the governor. The angle change will correct the engine speed to the desired value. Upon opening the motor circuit, the brake magnet which is connected in the circuit of both fields releases the brake disc, the lining of which is brought into contact with that of the brake plate by action of springs placed behind the disc. This action prevents the rotating inertia of the armature and the speed reducer gears from carrying the blades beyond the desired angle. This contact is maintained until current is again applied, at which time the two plates are drawn apart and the motor is free to turn. Automatic electric cut-out switches limit the angle range for ordinary operation and give high and low angle settings. When the switch is closed and the automatic

control engaged, the governor causes one side of the relay to be energized. The contact arm of the relay is drawn against the stop by action of the energized magnet and closes the circuit of the electric motor. The motor drives the power gear through the speed reducer and causes the blades to rotate in their socket. In feathering, the propeller may be rotated up to approximately 90° , at which point a third automatic electric cut-out switch stops the change of blade angle. Two types of controls (manual and automatic) are available for selection by the pilot, the change from one to the other being made by toggle switches located on the propeller control panel. When on automatic control, a selected engine speed is held constant by an engine-driven governor. Speed selection is accomplished by turning the propeller governor control handle located in the cockpit. When on manual control, the propeller acts as a fixed pitch propeller, the blade angle being varied by operation of the "increase r. p. m." or "decrease r. p. m." switch.

19. Description.—a. The power unit consists of the motor, brake, speed reducer, and drive gear (fig. 11).

(1) The pitch control motor is a 12-volt, series wound, direct current motor, and has a double field to provide for rotation in either direction. The aft end of the armature shaft is machined to fit into the drive shaft of the first stage of the speed reducer. The forward end of the armature shaft extends outside the motor case and is keyed to the magnetic brake.

(2) An aluminum alloy plate is keyed to the armature shaft and brake lining is fastened to the inner face of this plate. The brake magnet, consisting of a winding and a steel housing, is fastened to the motor case. A hole in the center of the core allows the armature shaft and brake plate hub to extend through the magnet. A steel brake disc, which has a leather clutch facing on its front surface, is mounted between the brake plate and the magnet. Studs are riveted to the brake disc. These studs, with a spring on the end of each, fit into corresponding holes in the magnet housing and insure a locked mechanism at all times when current is not flowing.

(3) The speed reducer is built in two stages of planetary type gearing. The low speed stage gives a reduction of 86:1, the high speed stage 171:1. This gives a total speed reduction of 14,706:1 for the two stages from motor shaft to drive gear. The unit is mounted in an aluminum alloy housing which is fastened to the propeller hub by bolts. The hub of the movable ring gear in the low speed stage is splined to receive the bevel drive gear. Electrical leads to the motor are carried through holes in the speed reducer

housing. The automatic limit switches are located in the lower rear part of the speed reducer housing. These are held in their normal position of contact against the contacts in the hub by springs. The switches cut out by means of a cut-out arm which is actuated by a cam located on the gear hub. A mechanical stop is also employed and consists of a plug extending through the rear speed reducer housing and a segment which is attached to the hub of the ring gear. It is adjusted to engage approximately 1° after the low limit switch has operated.

(4) The drive gear is a bevel gear made of steel with a splined hub. It is mounted in an adapter plate by means of a ball bearing, and, when assembled on the power unit, the splines of the power gear fit over those on the ring gear of the reducer. The adapter fits against the face of the reducer housing.

b. The hub assembly is made up of the hub and the slip ring assembly.

(1) The hub is a steel forging with sockets for three blades and is splined to fit a standard crankshaft. The front face of the hub is machined to fit the power unit housing.

(2) The slip ring assembly is attached to the rear part of the hub by screws which pass through the assembly and screw into holes in the face of the hub. The assembly consists of four brass rings separated by bakelite spacers and a case to hold them. Four electrical brass rod connectors are fastened to the slip rings and pass through holes in the hub to its front face where they make contact with the respective motor leads in the rear face of the power unit.

c. The blade assembly consists of the blade, blade nut, bearing stack, and blade gear.

(1) The blades are of hollow steel. The outside of the shank is machined to fit the stack of bearings and the inside of the blade is threaded to fit the blade gear. The blade gear is pinned to the blade to always insure correct relative position.

(2) A steel nut is screwed into the hub socket, thereby holding the blade assembly in place. Slots are provided for locking the nut to the hub socket. These slots also provide a means of correcting for "out of balance" by the addition of small weights in the slots.

(3) The blade bearings come in stacks of seven. They are ground to divide the load equally between them. A slight preload of the bearings is made possible by reversing the last bearing. This is to insure a rigid assembly at low engine speeds.

(4) The blade gear is a steel bevel gear with hub threaded to screw into the blade root. A small portion of the teeth of some assem-

blies are milled away to provide clearance for the split cone during installation of the propeller on the crankshaft.

d. The brush assembly consists of the housing and the brush cap assembly.

(1) The housing is an aluminum alloy casting, to one side of which is attached the brush cap assembly. It forms a cover over the slip rings when the propeller is installed.

(2) The brush cap assembly consists of an aluminum alloy cap to which bakelite holders and spacers are fastened. Duplicate carbon brushes are held against the slip rings by means of springs placed in the holder behind the brushes. Three wires are carried in the conduit which is fastened to the top of the cap. These wires are attached to three of the terminals, the fourth brush (feathering) not being used in a single-engine airplane.

20. Installation and removal.—a. Every propeller is completely assembled at the factory where proper shims and locking device are fitted. The propeller control unit is run in for a short time to assure proper functioning, after which it is disassembled into shipping units and packed. The instructions outlined in section IX will be followed when installing the propeller.

b. (1) Before installing the propeller, all component parts and controls are examined for defects and damage and checked for proper fitting. All corrosion and raised points of nicks, burs, galls, scores, etc., on joining surfaces of the attaching parts, hubs, and crankshaft end are carefully dressed off and the parts thoroughly cleaned before installation. In addition, the splines, cones, cone seats, etc., are coated with clean engine oil to provide lubrication and prevent corrosion. Cup grease or semifluid greases are not used for this purpose. The threads on the shafts are thoroughly coated with lubricant.

(2) Remove nuts (and spacer ring if provided) from thrust bearing cover studs on nose of engine and place brush housing on studs. Replace nuts, tightening and securing them. Leave brush assembly out of housing until propeller has been installed. When removing or installing propeller, the brush assembly is removed from the housing to eliminate possibility of damage to the brushes.

(3) Clean and lubricate cone. Place on shaft.

(4) Place propeller shaft locking adapter in end of shaft.

(5) Apply a coating of thread lubricant to threads on shaft and in nut, and a light coating of engine lubricating oil on the splines.

(6) On propeller hub designs 55012-2 and 55003-D, rotate blade assemblies (decrease pitch) until cut-away portion of blade gear is forward and install shaft nut, front cone, and snap ring. On designs

55014-B-4 and 55014-B-6, shaft nut, front cone, and snap ring are installed before shipping.

(7) Rotate blade assemblies back into normal flight range.

(8) Place propeller on shaft, being careful not to damage shaft threads or cone seats in the hub. Slide propeller on shaft until nut touches end of shaft, then carefully start nut on shaft threads and tighten by hand.

(9) With a 3- or 3½-foot bar through the nut, apply force of 250 to 300 pounds at end of bar to tighten nut.

(10) Apply a light coating of Prussian blue on ends of slip ring brushes and place them in the housing. Rotate propeller back and forth slightly. Remove brush assembly and check location of brush contact on slip rings as indicated by the Prussian blue. The brush track should be in the approximate center of the slip rings and not closer than .020 inch to the slip ring separators. If brushes are not correctly aligned, remove propeller and place one or more stainless steel shims (furnished with propellers) between rear cone and thrust nut, or shims between engine nose and brush housing. When alinement is satisfactory, clean brushes and slip ring and install brush assembly.

(11) Fit locking tube to adapter inside propeller shaft nut so that a clevis pin hole lines up with the hole in the nut. Specific instructions on the safetying for each type of installation may be found in Air Corps Technical Orders.

c. Two types of blades and power unit indexing systems are used; the first type being used on the 55012-2 and 55003-D-2 propellers, and the second on the 55014-B-4 and 55014-B-6 propellers. They are as follows:

(1) Index marks on power gear and steel adapter plate and index marks on blade gears which aline with corresponding marks in the hub.

(2) Index marks indicating a series of blade angles on blade shanks just outside of the hub, and a series of marks inside the power gear.

(3) To index propellers 55012-2 and 55003-D-2, check alinement of index marks on power gear and on steel adapter plate. To aline these index marks, it will be necessary to remove the steel mechanical stop which is held in place by bolts just forward of the steel adapter plate. This is done to eliminate possibility of damaging the speed reducer when attempting to aline the two index marks. After the mechanical low angle stop has been removed, the power gear is rotated by applying 12-volt current to the pitch change motor through the increase or decrease pitch contacts and allowing the power unit to run until the desired position is reached. Turn blades in hub until index tooth on each blade gear lines up with the mark scribed on inside of hub.

(4) To index propellers 55014-B-4 and 55014-B-6. On the blade shanks are acid stamped lines which indicate blade angles when alined with the index line on the front of each blade socket. The power unit splined shaft has a master or index spline which is indicated by a radial mark across its end. The power gear has marked spline spaces in steps of 1° . The angle indicated on the power gear nearest the master spline is the low pitch for which the propeller is adjusted. To install the power unit with this system, the following procedure is used:

(a) Remove power gear and adapter plate from power unit and see that the low limit cut-out switch is just riding on the low limit cam lobe. If it is necessary to run the power unit to properly locate cam, proceed as outlined in (3) above. Then replace power gear, having master spline in line with the mark indicating the desired low blade angle.

(b) Aline marks on hub and marks on blade shanks, indicating the desired low blade angle (same angles as power gear).

(c) Install felt grease seal over propeller shaft.

(d) Clean contacts on face of hub and their mates in the power unit. Then place power unit on hub, alining contact points and bolt holes of power unit and hub. Push firmly against hub so that power gear meshes with blade gear. Secure unit tightly to hub with the six attaching bolts and safety.

(e) Replace mechanical low stop in proper hole alining the mark "O" stamped on stop and housing and check blade angles.

(f) Install speed reducer cover and safety screws.

(5) After the propeller has been completely installed, the dial on propeller control is adjusted to agree with the tachometer. While the engine is running, throw master switch to "automatic" and adjust crank until tachometer reading is approximately in the middle of its normal flight range. Disconnect flexible control shaft at control unit and adjust dial to correspond to tachometer reading, then replace shaft.

NOTE.—On some installations, the reading of the dial on the control unit will vary approximately 50 r. p. m. from the tachometer reading, therefore for the final adjustment of the governor, the tachometer reading is the criterion.

d. The method of removing propeller from crankshaft is the reverse from installing it; however, the procedure below is followed:

(1) Operate power unit until minimum blade angle is obtained. This can be determined by observing the lines scribed into the paint on hub and blades, or by checking with universal propeller protractor. If not already accomplished, paint a small area of the hub and blades and scribe a reference line into the paint for adjusting on rein-

stallation. On some contracts, this marking on the hub and blades is performed at the factory.

(2) Remove brush assembly from housing.

(3) Remove motor and power unit covers.

(4) Remove power unit.

(5) Remove locking pin and tube from crankshaft.

(6) Unscrew retaining nut. This will draw the propeller from shaft.

Care is exercised in removing propeller from shaft to prevent damage to threads of crankshaft. The power unit with the covers removed will not be left exposed for any length of time.

21. Lubrication.—The following lubrication periods are observed and the lubricants specified are used:

a. Before installing propeller on crankshaft, completely fill hub through cavity showing blade and gears with specified lubricant. Propellers assembled for stock purposes are lubricated only sufficiently to prevent corrosion.

b. Fill power unit through filler hole with specified lubricant.

c. Pack governor drive shaft with specified lubricant.

d. After power unit is installed on propeller, check level of oil in speed reducer by removing filler plug and rotating propeller until filler hole is approximately 20° below horizontal. The oil should then be level with filler hole.

e. Fill hub with lubricant. This is accomplished by filling through one of the fittings located on the speed reducer housing, with one blade down. Use bottom fitting to fill and remove top fitting for vent. The hub will be filled when lubricant appears from top hole.

22. Propeller controls.—a. The constant speed control consists of a governor which is regulated to keep the engine at a constant speed by regulating the pitch of the propeller to absorb more or less power, thereby decreasing or increasing the engine speed to bring it to the value set on the governor. Proper switches for operating the system either automatically or manually, working in conjunction with a relay and all necessary conduit, wire, etc., are a part of the propeller controls.

b. The governor consists of a revolving spindle upon which are pivoted spring loaded flyballs, a means of changing the spring pressure, and a switch arrangement. The forces created by the spring load and the centrifugal force of the flyballs oppose each other and jointly control the position of a contact operating rod. The speed of the spindle depends on the type of governor and type of engine on which it is installed. The contact operating rod operates a spring loaded movable contact point which moves between the two fixed contact

points. When flyball forces overbalance the spring load, contact is made with the governor switch fixed contact point, closing the increase pitch or decrease r. p. m. circuit. When the spring load overbalances the centrifugal force on the flyballs, contact is made with the opposite circuit which decreases the pitch and increases the r. p. m. Spring loads are adjusted by turning a screw which causes a threaded adjusting block to move back and forth along its length, thereby decreasing or increasing the spring load. This screw is turned by a flexible shaft from the pilot's cockpit. The governor is driven by a tachometer shaft attached to one of the engine tachometer drives. A 1: 2 adapter is inserted in the drive line so that the flyballs turn at the same speed as the engine.

c. The governor control (fig. 12) is attached to the face of the engine control quadrant in the pilot's cockpit. The housing supports a small crank which turns a worm gear meshing with a gear on the drive shaft. A movement of this crank increases or decreases the compression on the governor spring, with a resultant change in the governor speed, at which sufficient centrifugal force is developed to move the plunger. An extension of the drive shaft carries another worm which turns a gear attached to an indicator dial. The dial is graduated in engine r. p. m. and has a stop to limit its travel on the inside of the dial. The calibrations on the dial are for approximate adjustment only. The engine tachometer is the primary indicator of the governor adjustment.

d. The relay consists of a switch arm pivoted between two fixed contacts and controlled by two magnetic coils mounted on opposite sides of the arm. The magnetic coils are energized by either the constant speed governor or the manual control switch. When the coil on one side of the switch arm is energized, the switch arm leaves its normal neutral position and closes the propeller pitch change circuit which flows through the switch arm and fixed contact point to the electric motor. The two fixed contact points of the relay are connected to oppositely wound fields of the electric motor. The motor rotates in either direction depending on which contact has been closed.

e. (1) The safety switch is a snap switch equipped with a thermal overload relay which automatically throws the switch to an "off" position, breaking the circuit after a predetermined period of overload. After the overload relay has cooled sufficiently, the switch is placed in the extreme "off" position after which it can be moved back to the "on" position, thereby closing the circuit again. Because of this feature, the switch is considered superior to a fuze.

(2) The manual control switch is a standard momentary contact snap switch having two throws and an intermediate "off" position. The switch is held in the "off" position by a spring. When it is desired to close the increase or decrease r. p. m. circuit, the switch must be held in the correct contact position. When it is released, it snaps to the "off" position. The function of this switch is to provide a manual control for increasing or decreasing the r. p. m.

(3) The selector switch is a standard switch having three positions. It is used to switch the power supply into either the manual control circuit or the constant speed control circuit.

(4) The "feathering" switch is a two-position snap switch. When it is thrown into the feather position, the increase pitch circuit is closed and remains closed until it is broken by the feathering cut-out switch (on the power unit). When the switch is in this position, the manual and automatic control circuits are broken. When the feathering switch is thrown to the normal position, the manual and automatic control circuits are closed and the feathering circuit is broken. The function of this switch is to feather the blades independently of the other control circuits.

f. When installing the controls, it is essential that the instructions outlined below be carefully carried out because a slight deviation from the method given may result in very serious consequences.

(1) The control is installed on the front face of the standard engine control quadrant. The control housing is fastened to the engine quadrant in place of the cover, which is removed from the quadrant by removing screws and the control knob. Before assembling the control instrument to the quadrant, it is necessary to remove the gear housing cover. This is accomplished by slipping off the pointer and dial, by removing the drive pin holding the crank handle on its shaft, and by unscrewing the screws holding the cover to the housing. The housing is then fastened to the quadrant and the control unit reassembled.

(2) The governor is normally mounted in the engine compartment. Details of mounting are to be worked out at engine installation. Things to be considered are accessibility of the inspection plate covering the contact points and the fact that the cover on the control side of the governor must be removed for adjustment purposes. It is recommended that the governor be mounted in a horizontal position. The tachometer shaft with a 1 to 2 adapter is connected to the governor drive which operates at engine speed. The speed of this drive is twice that of the tachometer drive on the engine. The flexible control shaft is connected to the governor and the control unit in the cockpit.

(3) The relay may be mounted in any convenient place in the engine compartment. The main considerations are shortest possible leads to the battery and propeller; and accessibility of points. Care should be taken that no part of the container is allowed to short the relay and that the base is kept flat to prevent warping.

(4) The control switches are installed in the pilot's cockpit in such a location and position that they can easily be reached by the pilot. Ample space should be allowed for making all electrical connections.

23. Operation.—*a.* When starting the engine, set safety switch to "on" position. This switch is on at all times. Set selector switch to the "automatic" position. Start the engine. If propeller is not already at low pitch (high r. p. m.) position, the electric motor will decrease the angle until the minimum angle is reached.

b. For take-off, set selector switch to "automatic" and propeller control for "take-off" r. p. m. It should be remembered that the calibration of the control dial is only approximate, as the engine tachometer is the primary indicator for close adjustment of the governor. Adjust throttle to obtain desired manifold pressure.

c. During climb and level flight, with the selector switch in the automatic position, the governor holds the engine speed constant by varying the angle of the propeller to suit different engine speeds or flight conditions. If a different engine speed is desired at any time during flight, it is necessary only to turn the control handle slowly until the tachometer registers the proper speed. Any combination of engine r. p. m. and manifold pressure is obtained within the operating limitations of the engine by independent adjustment of the engine throttle and propeller control. When the cruising altitude has been reached, turn propeller control handle to cruising r. p. m. and throttle to its cruising position. Switch propeller to "manual" position. By watching the r. p. m., the best setting of the mixture control is obtained, after which the propeller may be switched back to "automatic" or the flight may be continued with the switch in the "manual" position. It will be found that manual operation during prolonged cruising does not require any undue amount of attention, and the saving in battery current and wear on the propeller control mechanism is appreciable. The manual control also has the function of an auxiliary control. In case of failure of the governor, satisfactory performance may still be maintained.

d. When gliding in to land, set selector switch to the "automatic" position. Adjust propeller control to cruising r. p. m. As the throttle is closed, the propeller automatically returns to the low blade

angle. A setting for cruising r. p. m. will prevent overspeeding of the engine if throttle is opened in case of an emergency.

e. When "feathering" the propeller as an emergency measure, set feathering switch to feather position. Close throttle. Move mixture control to idle cut-off position. Turn off fuel supply. Leave ignition switch on until propeller stops rotating.

f. As part of routine training or for practice, the propeller is feathered in a slightly different manner. Close throttle. Move mixture control into idle cut-out position. Turn off supply of fuel to engine. Set feathering switch to "feather" position. Leave ignition switch on until propeller stops rotating.

g. To return from feathering (unfeathering), turn ignition switch "on" with the throttle closed. Set propeller control to high pitch (low r. p. m.) position. Turn on fuel supply. Move mixture control to full rich position. Set feathering switch to normal position and selector switch to manual. Hold momentary switch (increase and decrease r. p. m.) in the increase r. p. m. position until tachometer reading reaches 800 r. p. m.; then release switch. Allow engine to operate at this r. p. m. until the required temperature is obtained. Set selector switch to automatic position and open throttle gradually to speed for which governor is set. Adjust mixture throttle and governor to desired power and engine r. p. m. It is important when unfeathering a propeller after the engine has cooled to run engine at a slow speed until its operating temperatures are reached, otherwise serious damage may result. The windmilling action of unfeathering is a very powerful cranking force and will overspeed the engine unless care is taken to stop the propeller at approximately 800 r. p. m. After unfeathering to about 800 r. p. m. at an airspeed of approximately 125 m. p. h., the engine may be permitted to warm up as long as desired without overspeeding.

24. Inspection and inspection maintenance.—*a.* At the specified periodic inspection, the range of operation of the Curtiss controllable propeller is checked as follows:

(1) Set throttle to give an engine r. p. m. within operating range of propeller governor.

(2) Move propeller switch to the "manual" position.

(3) Hold momentary switch in the "increased" r. p. m. position. Note increase in engine r. p. m. When no further change is indicated on the tachometer, the propeller is in full low pitch position.

(4) Position and hold momentary switch in the "decreased" r. p. m. position, and note decrease in engine r. p. m. When no further

change is indicated on the tachometer, the propeller is in high pitch position.

NOTE.—During the above checks the throttle is not moved.

(5) Move propeller switch to the "automatic" position.

(6) Adjust r. p. m. selector or control to give maximum r. p. m. Note increase in engine r. p. m., and when no further increase is indicated by the tachometer, the governor is functioning and the propeller is in low pitch position.

(7) Adjust r. p. m. selector or control to give minimum engine r. p. m. Note decrease in engine r. p. m., and when no further change is indicated by the tachometer, the propeller is in full high pitch position.

(8) Return propeller to low pitch position for take-off.

b. The cockpit control, switches, relay, and governor are inspected for security of mounting. Brackets are inspected for cracks and other damage; for loose or damaged screws, bolts, and pins; and for freedom of movement. Any damaged part will be replaced with a serviceable one before flight.

c. Remove brush holder cover plate by taking out screws and inspect for evidence of carbon dust, oil, dirt, etc., particularly at the bottom of the housing. Remove such substances when found. Remove brush holder cap by loosening flexible conduit joint and removing wing nuts. Check brushes for excessive wear and accumulated carbon dust, oil, and dirt. Clean thoroughly by using compressed air and some noninflammable cleaning fluid. Check brushes to make certain they are working free and make good contact.

d. Inspect relay for broken terminals, free action of the arm, and smoothness of contact points. The middle contact point should rest squarely against the fixed ones when in either of the two contact positions. In case of a failure to function, the relay is removed from the box by removal of screws. If necessary, contact points are replaced, observing the caution that contact over the whole surface of the points is to be obtained. Remove relay box cover and seal and check for accumulated carbon, oil, dirt, etc., particularly at bottom of box and behind bakelite panel. A flashlight will probably be necessary to determine whether there is any inflammable material near the contacts.

e. Procedure for checking retaining nut for looseness is as follows:

- (1) Remove motor and power unit cover.
- (2) Remove power unit. The power unit is secured to the hub by bolts.
- (3) Remove locking device.

(4) Insert a 3- to 3½-foot bar into retaining nut. Apply a weight of 250 to 300 pounds on end of bar. The bar is applied steadily; avoid jerking it.

(5) Install locking device.

(6) Turn blades (if they are not marked) until indexed tooth of blade gear aligns with reference lines in hub.

(7) Remove mechanical stop from power unit and operate electric motor until indexed tooth on power gear aligns with reference line on adapter.

(8) Install mechanical stop and resafety.

(9) Install power unit and secure it to the hub with bolts. Safety all bolts with wire. Do not disturb setting of blades when installing power unit.

(10) Install power unit and motor covers and safety all screws with wire.

f. The brush holder is removed by disconnecting flexible conduit, removing wing nuts or clamps and disconnecting wire terminals under cover plate. The brush holder assembly is then thoroughly washed with cleaning fluid, preferably nonflammable. Dry with compressed air. Replace all worn brushes or other damaged parts. The slip rings and the inside of brush housing are thoroughly cleaned with a cleaning fluid and dried with compressed air.

g. Remove inspection plate and examine contact points for pitting and proper clearance. When the engine is not running, the middle contact should rest against the decrease pitch point and the gap between the middle and the adjustable contact should be 0.025 to 0.030 inch.

h. When checking the magnetic brake, the nose cap of the power unit must be removed. Determine if the brake disc is engaged against the lining of the brake plate when the current is off, and upon application of the current, if the disengagement is effected immediately. Glazing of the brake lining is removed with a coarse file. Any looseness of the brake plate with respect to the motor shaft is noted and the lining checked for excess wear. The gap between the brake lining on brake plate and the clutch facing on brake disc is checked for proper clearance. This gap should be 0.015 to 0.020 inch. Use a gage to make the check. Care is exercised that the gage is inserted between the brake lining and the clutch facing in the direction of rotation of the motor shaft.

i. The relay box cover and seal are removed and relay disconnected and removed from box so that contact points can be inspected.

(1) On some relays, conventional material is used for the contact points. If these points show excessive pitting or piling up of contact

material, they will be dressed down with a fine-cut file, such as an ignition contact point file. If an excessive amount of metal is removed, the relay is replaced.

(2) On other relays, a special Elkonite point material is used. Discoloration and fine pitting of these points are normal and will not increase the resistance or their tendency to stick in operation. The Elkonite points are not filed or stoned since this only shortens the life of the points.

(3) Both types of relay points are checked for proper alinement of the contact surfaces. If there is sufficient wear of the center switch contact arm bearing and centering spring to allow the contacts to strike due to jar, without electrical operation, the relay is replaced.

(4) Thoroughly clean relay box and relay since any inflammable substance may be ignited in operation by arcing of relay points.

(5) Install relay panel in box, reconnect wires, seal conduits, attach cover, and safety.

j. In this particular type of propeller, which depends on the electrical system for power to change the blade angle, most of the maintenance problems are electrical. Checking all terminals, connections, brushes, etc., is the first step in locating the source of trouble. If this fails, the trouble may be in the power unit or propeller, which would require the services of trained propeller mechanic to locate and correct the condition. Exceptions as follows:

(1) Occasionally the flexible shaft from the r. p. m. control to the governor is not properly seated or in mesh. This will be noticed during operation in the "automatic" position. Any change of the r. p. m. control will have no effect on the engine r. p. m. This is corrected by removing the control and properly seating it and making sure the control is in mesh at both ends.

(2) If at any time the propeller will not change angle in either the "manual" or "automatic" position and all wiring has been checked and found correct, then check magnetic brake for clearance.

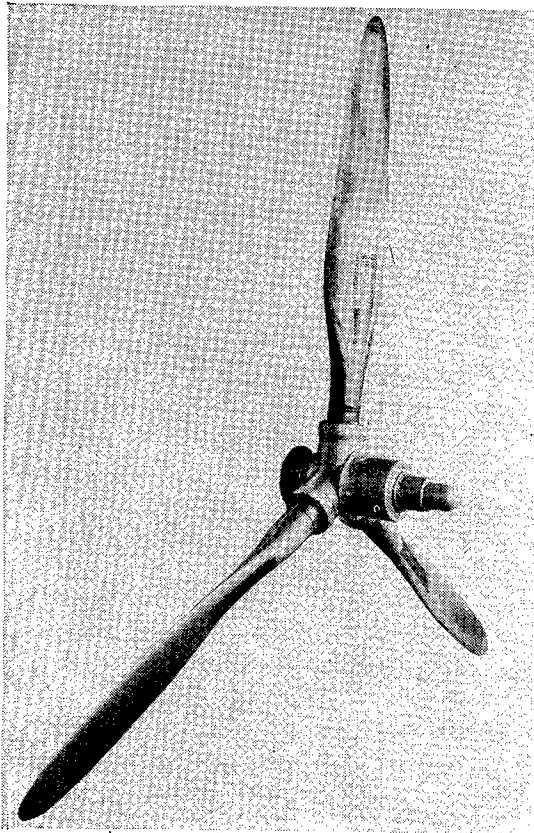


FIGURE 10.—Curtiss controllable propeller.

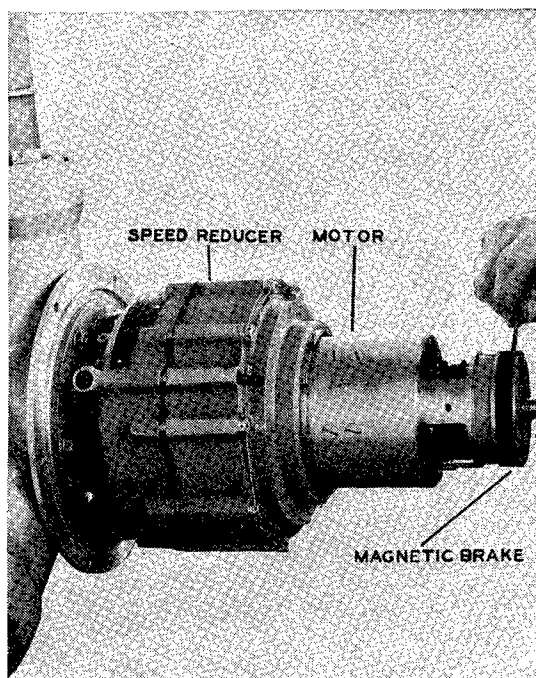


FIGURE 11.—Power unit and brake.

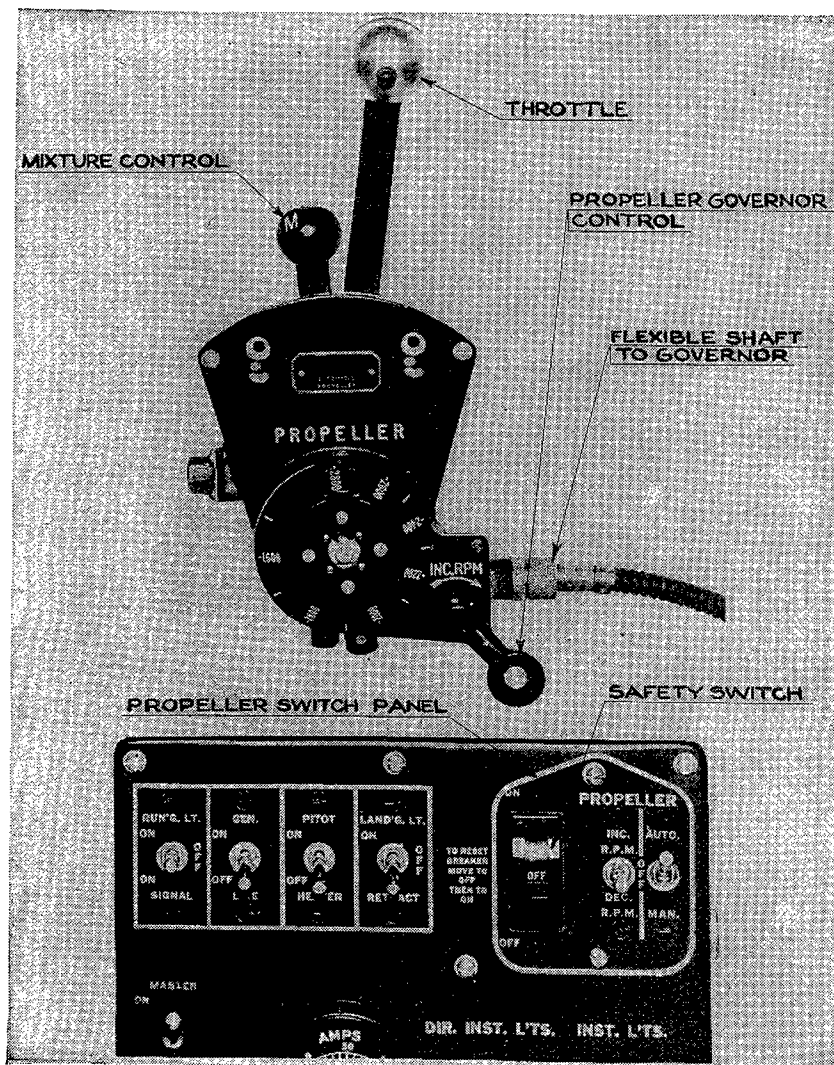


FIGURE 12.—Cockpit control crank and dial.

SECTION V

HAMILTON STANDARD TWO-POSITION PROPELLER

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25. Principle of operation.—*a.* An oil pressure line from the main pressure supply in the engine is conducted to a three-way valve, and thence through a collector ring into the interior of the front end of the crankshaft and out into the pitch operating cylinder (fig. 14). The three-way valve is so arranged that rotation of the valve stem will cause the oil line leading to the propeller to be connected with the pressure supply in one position or with a drain directly into the crankcase in the other position. When this oil valve is thrown into the pressure supply position, the oil flows through the collector ring into the crankshaft and out into the cylinder, causing the cylinder to move forward on the piston.

b. As the cylinder moves forward, the counterweight bearing shaft, which is attached to the base of the cylinder, moves in the cam slot of the counterweight bracket. This bracket is attached to the blade bushing by means of index pins. As the bearing shaft moves up the cam, it causes the bracket to turn. This turning of the bracket is transmitted to the blade, rotating it to high r. p. m. (low pitch) position.

c. When the three-way valve is turned to the "off" position, the oil pressure on the cylinder head is released. On the arm of each blade bracket is a counterweight. The centrifugal force generated by these counterweights turns the brackets and rotates the blade to the low r. p. m. (high pitch) position.

d. Most of the later high-powered engines incorporate a built-in valve as standard equipment. Adaptions for other engines have been worked out by the engine manufacturers.

e. The action of the hydraulic and counterweight controls is such that extra force is available for movement into high r. p. m. (low pitch) when the revolutions are below the normal value, and extra control forces are available for going into low r. p. m. (high pitch) when the revolutions are above the normal value. A typical Hamil-

ton standard two-position propeller is shown in figure 13. The oiling system of this propeller is shown in figure 14.

26. Description.—The various units of this propeller are shown in figures 14 and 15. Following is a brief description of the principal units:

a. The spider is made from heat-treated steel forgings. Through the arms of the spider the principal forces are transmitted between the blades and the propeller shaft.

b. The barrel is of steel and is cadmium plated. It takes up the centrifugal force of the blades. A micarta bushing which fits around the bottom of the spider prevents the barrel from chafing the spider.

c. Oilite shim plates protect the spider from galling. On some propellers, a formica strip is attached to their circumference preventing chafing of the barrel. To insure a reasonably tight over-all fit of the parts which are held between the spider and the barrel, laminated shims are peeled to the required thickness and placed between the shim plates and the spider.

d. The piston is of steel. Its base is threaded to fit on the engine crankshaft. A shoulder is turned at the outer end of the piston on which gaskets fit. These gaskets form an oiltight surface between the cylinder and the piston and serve as a guide to the cylinder as it moves back and forth.

e. The cylinder is of aluminum alloy. A steel liner is installed in the cylinder to prevent the piston gaskets from wearing its inner surface. Threaded holes are located in the flanged base of the cylinder, one opposite each spider arm. A stop plug at the base of each hole limits the distance; the bearing shaft can be screwed into the cylinder, thus assuring the proper fit of each bearing assembly. A bronze bushing in the outer end of each hole prevents the bearing shaft from wearing the aluminum cylinder.

f. The counterweight bearing shaft is of steel. One end is threaded to fit the cylinder holes. The other end consists of a cone which fits the seat in the cap race, and a short extension of the shaft which contacts adjusting nuts and limits the travel of the counterweight bearing shaft.

g. The counterweight bearing consists of a curved steel race, a curved bearing retainer, and a circular steel cap race. The curved (inner) race fits snugly into the cam slot of the counterweight bracket. The circular cap race has a seat on its outer side, into which the cone on the bearing shaft fits. The retainer is held in place, between the two races, by means of the bearing shaft.

h. The counterweight bracket is of steel. The outer end contains the cam slot in which the counterweight bearing moves. The other end fits around the blade bushing. The portion of the bracket next to the blade bushing is scalloped with 40 semicircular holes. Four of these semicircles can be matched with four of the 36 semicircles which compose the base circumference of the blade bushing. Index pins, tapped into the four aligned sets of semicircles, assure the translation of any lateral turning movement of the bracket into a rotating motion of the blade.

i. A steel counterweight is fastened to the outer face of the bracket by fillister screws. A slot in the counterweight corresponds to the cam in the bracket. It is up and down this slot that the cylindrical extension of the bearing shaft moves. Along one side of this slot is a scale. It has degree graduations which are stamped during final assembly and correspond with protractor measurements of the blade at the 42-inch station. Toward one end of the slot is a lead fillet on which is stamped the base setting of the blade.

j. The adjusting screw with its nuts fits into the slot in the counterweight. It is held from turning by a pin. The nuts may be turned up or down the screw, independently of each other, to any desired position indicated on the stamped scale. As the bearing shaft moves in the cam, its extended end contacts these nuts, thus limiting the pitch setting of the blades.

k. A counterweight cap screws on the face of the counterweight. It acts both as a protecting cover for the adjusting screw and as an added weight whose centrifugal force will help pull the blades into the high pitch setting.

l. The blade shank is of the semihollow type. The semihollow construction makes it possible to almost double the bending strength of the inner portion of the blade without excessive increase in weight.

m. The taper bore of the blade end with its tapered bushing, together with the form of the outside of the blade, provides almost complete freedom from any tendency toward localization of stresses which might cause the blades to break at the shank.

n. The thrust bearing assembly consists of two thrust rings which cannot be removed from the blade, and a split thrust bearing retainer. These roller thrusts bearings are designed for a high capacity. In spite of the great centrifugal forces, they permit the blades to rotate with minimum friction.

o. The design of the roller bearing races makes possible the use of extremely large fillets with resulting increase in resistance to fatigue. The location of the roller bearing around the outside of the blade,

in conjunction with the centering action of the spider on the inside of the blade, permits a large roller area without excessive weight.

p. Blade bushings are of aluminum bronze. They are pressed tightly into the hollow blade ends and secured by drive pins and lock screws. Care is not only taken to assure correct alinement between the inside of the bushing and the blade face, but also to make certain that the semicircles on the circumference of the bushing base are in proper relationship to the blade pitch.

27. Installation and removal.—Before installing the propeller, the applicable provisions for preparing the crankshaft for installation as listed in section IX are followed.

a. The installation of a Hamilton standard two-position propeller is accomplished in the following order:

- (1) Remove plug from crankshaft and clean the inside.
- (2) Install bronze rear cone and rear cone spacer (if used) on engine shaft against thrust nut. On direct drive Wright engines, screw oil supply pipe without gasket into oil plug, which is located inside the crankshaft. Do not pull up oil supply pipe connection too tightly, as this is likely to swage the internal oil supply pipe in the crankshaft sufficiently to choke off the oil supply. On geared Wright engines, the oil supply pipe gasket is used with the oil supply pipe.
- (3) Remove cylinder head lock wire and unscrew cylinder head. Remove lock ring from hexagon portion of piston. On propellers for Wright engines, remove piston gasket nut, oil pipe packing nut, and packing. The piston gasket will now be loose and is removed in order to prevent damage. The piston gaskets are left in place on other installations.
- (4) Place propeller on crankshaft. Make sure that piston and crankshaft threads are in perfect alinement. In no case should force be used to tighten the piston if there is binding or indication that the threads are not properly started, as serious damage may result. Where it is found that due to handling or reassembling without proper bushings the piston and shaft are not in alinement, the counterweights are disassembled and the bearing shafts removed. This frees the cylinder and piston to permit easy starting of the threads and proper tightening of the propeller on the shaft. The counterweights are then reassembled. Care is taken in tightening the piston to see that the front cone packing washer, when one is required, does not bind but is pulled properly in place. As an aid in installation, it is suggested that the piston be tightened a few turns and then the hub jarred slightly by hand. This will help prevent jamming the washer into the shaft threads.

AIRCRAFT PROPELLERS

(5) Insert proper wrench and tighten piston using a bar 4 feet long. Apply a force on the end of the bar of approximately 175 pounds. One man of average weight (175 pounds) using a bar of this length can usually tighten the piston sufficiently without the need of additional leverage or the use of a hammer on the bar. The force is applied steadily on the bar.

(6) Secure piston with lock ring. Safety lock ring, using steel cotter pins. The heads of these pins are toward the crankshaft.

(7) On propellers for Wright engines, install piston gasket nut and safety. On other engine installations, check to see that piston gasket nut is safetied. On propellers for Wright engines, put supply pipe packing and packing nut in place, tighten packing nut and secure with safety wire.

(8) Install cylinder head gasket on cylinder head. In order to avoid possibility of the gasket becoming damaged during assembly, care is taken to insure that it is properly held in place on the pilot of the cylinder head. This is accomplished by either the use of heavy grease or by lightly tapping the gasket with a hammer while it is on the cylinder head.

(9) Before installing the cylinder head, thoroughly coat threads on cylinder head and in cylinder with thread lubricant. Extreme care is exercised when installing the cylinder head to insure that threads are properly started. Tighten cylinder head sufficiently to prevent oil leaks, using the proper wrench with a leverage of not more than 18 inches.

b. The method of removing the propeller from the crankshaft is as follows:

(1) Before propeller is removed from the crankshaft, blades are placed in the low r. p. m. (high pitch) position. Use blade beams to change blade angle. Never use a hammer or mallet on blades, cylinder head, or counterweights when changing position of the blades.

(2) Disengage cylinder head lock wire and remove cylinder head. A container is used to catch the oil from the cylinder when cylinder head is removed. On Wright engines, loosen supply pipe packing nut and unscrew piston gasket nut.

(3) Disengage piston lock ring by removing cotter pins. It is good practice to slide the lock ring up on the piston. The propeller should be in the high r. p. m. (low pitch) position to remove the cotter pins.

(4) Unscrew piston. This will start the propeller off the engine shaft.

(5) Slide propeller slowly forward on engine shaft and remove. Take care not to damage the threads of engine shaft. On Wright engines, care is taken not to damage the oil supply pipe.

28. Lubrication.—Before the propeller assembly is installed on the engine or if the propeller is assembled and placed in storage, the hub spider is filled and the counterweight shaft bearings thoroughly coated with grease.

29. Propeller control.—*a.* Engines are adapted for the two-position propeller by extending the engine oil pressure system through the crankshaft or propeller shaft to operate the propeller mechanism. This pressure is controlled by a three-way valve located in most cases on the nose of the engine. This valve is operated from the cockpit by a push-pull or quadrant type of control. The control is either a pulley and cable or torque rod arrangement, depending on the type of airplane on which it is to be installed. Suitable stops in the cockpit prevent unnecessary strains on the control valve unit. The travel of the control lever on the three-way valve is limited by projections of the valve mounting studs. In operation, the cockpit control is moved forward (if mounted horizontally, and down if mounted vertically) to open the three-way valve which allows oil to flow into propeller cylinder, forcing the propeller into low pitch (high r. p. m.) position. A movement of the control to the rear (if mounted horizontally, and up if mounted vertically) will cause the valve to be moved to the drain position, which allows the oil to flow back to the crankcase, and the propeller goes into high pitch (low r. p. m.) position. Figure 16 shows a typical single-engine installation of the controls.

b. The controls are installed by the airplane manufacturer. However, in event it is desired to install propeller controls, a standard Air Corps drawing should be consulted and the directions followed.

30. Operation.—General operating instructions are as follows:

a. The test of operation is judged by observing the changing of pitch during the process of running up. This is observed by watching the travel of the cylinder on the front of the propeller or by watching the change in r. p. m. on the tachometer. In this connection, it should be borne in mind that hydraulic pressure changes the blade angles from low r. p. m. (high pitch) setting to high r. p. m. (low pitch) whereas centrifugal force acting on the counterweights changes the blade angles from high r. p. m. (low pitch) to low r. p. m. (high pitch). Therefore, the shift from high r. p. m. (low pitch) to low r. p. m. (high pitch) is accomplished more rapidly at high engine r. p. m. because of the greater centrifugal force generated.

Conversely, shifting from low r. p. m. (high pitch) to high r. p. m. (low pitch) is more rapid at lower engine speeds when centrifugal forces are of lower value.

b. Prior to starting the engine equipped with a two-position Hamilton standard controllable propeller, the control is placed in the "decreased" r. p. m. position in order to avoid possible lack of oil to master rod bearings.

c. After starting, the engine will be run for approximately 1 minute in the "decreased" r. p. m. position, after which the propeller is shifted into the "increased" r. p. m. (low pitch) position and maintained in this position during the warm-up. With the propeller in the "increased" r. p. m. position check engine r. p. m. at full throttle.

d. For take-off and climb, the propeller control is placed in the "increased" r. p. m. (low pitch) position until the altitude is reached at which level flight is intended. Overspeeding of the engine is avoided by use of the throttle. As maximum efficiency is essential when in a climb near the ground after take-off, propellers should not be shifted to low r. p. m. (high pitch) position until an altitude of at least 1,000 feet has been obtained, unless level flight is to be assumed at a lower altitude. Where the rate of climb is below normal, the engine is throttled slightly to prevent excessive r. p. m.

e. The propeller control is placed on the "decreased" r. p. m. (high pitch) position for normal level flight.

f. During glides and landing, the propeller control is placed in the high r. p. m. (low pitch) position for the most effective use should an emergency take-off become necessary.

g. For the purpose of preventing exposure and corrosion of the propeller piston on an idle engine, the propeller cylinder is withdrawn by shifting the propeller to the "decreased" r. p. m. position prior to stopping the engine. To inspect the propeller cylinder for galling and wear, the engine is stopped with the propeller control in the "increased" r. p. m. position.

31. Inspection and inspection maintenance.—*a.* As part of a periodic inspection, the range of operation is checked as follows:

(1) When the engine has been warmed up to the specified operating temperature, set throttle to give approximately 1,400 r. p. m. with propeller control in low pitch (high r. p. m.) position.

(2) Shift propeller control into high pitch (low r. p. m.) position and note decrease in engine r. p. m. on tachometer. This decrease in engine r. p. m. denotes propeller is functioning correctly, the amount of change depending upon the range of the propeller.

(3) Without changing position of the throttle, move propeller

control to low pitch (high r. p. m.) position and note increase in engine r. p. m. This change signifies propeller is going into low pitch (high r. p. m.) position.

b. A loose cylinder head or a damaged cylinder head gasket will allow oil to leak from around the cylinder head. This leakage will be noticed during the warm-up and is corrected before flight. A damaged piston gasket or loose piston gasket nut will allow oil to leak from around the base of the cylinder.

c. An inspection is made of all barrel bolts, piston lock ring, cylinder head, counterweight bearing shaft, and counterweight cap to determine the condition of the safetying devices. Replace all worn or damaged cotter pins and lock wires. Position heads of pins so that centrifugal force will tend to hold pin in place in case of a failure.

d. At the specified periodic inspection, remove cotter pins from piston lock ring and disengage the ring; the propeller should be in the low pitch position. With the aid of blade beams, turn blades to high pitch position and remove cylinder head lock wire and cylinder head. Insert proper wrench into head of piston. Use a bar approximately 4 feet in length and weight of an average man on the end of the bar to check piston for looseness. No extension nor hammering on end of bar is permitted. Replace cylinder head and cylinder head lock wire. Turn blades to low pitch position and reposition piston lock ring and safety. On Wright engines, the supply pipe packing nut and piston gasket nut are removed before attempting to check the piston for looseness.

e. The propeller control in the cockpit is checked for security of mounting and freedom of movement. All bell cranks, rods, tubes, and cables are inspected for defects and corrosion. Determine by movement of cockpit control that operating arm of the three-way valve has full range of movement. Coat all controls with clean engine oil.

f. With propeller in full low pitch (high r. p. m.) position, clean exposed portion of piston with kerosene, gasoline, or some approved cleaning fluid. Inspect piston for wear, corrosion, galling, etc.; remove any defect by careful handstoning with fine sandpaper or crocus cloth. Coat surface of piston with clean engine oil. Place propeller in full high pitch position.

g. During normal operation, maintenance problems may develop which can be corrected by the airplane mechanic. A number of such problems are given below. In event the correction requires the disassembly of the propeller, the services of a trained propeller mechanic should be obtained.

(1) A slight trace of grease between the barrel and blades after flight is considered normal, but when it becomes excessive the condition is corrected. First ascertain from where the grease is coming. It may be that during the lubrication of the hub spider, grease has leaked from, around the grease fitting. This will collect in the cavity between the barrel and blades and during engine operation will be thrown out. If this is not the case, the propeller should be removed from the shaft and the grease retainers replaced, which would require disassembly of the propeller.

(2) During warm-up, the cylinder runs eccentric when in low pitch (high r. p. m.) position. This is usually due to the fact that the projection of the counterweight bearing shaft is not striking the upper adjusting nuts simultaneously. This may be corrected by stopping the engine in full low pitch (high r. p. m.) position and removing the counterweight caps. Check counterweight adjusting screws to see if they are held tightly by counterweight bearing shaft bearing against adjusting nuts. If one or more counterweight adjusting screws are found loose, make corrections by adjusting nuts until they all bear against counterweight bearing shaft at the same time. If any adjustment is made, the blade angle of the propeller is checked.

(3) Engine oil leaking from around the cylinder head is easily corrected. First check cylinder head for tightness, using proper wrench and leverage. If this fails to correct the condition, remove cylinder head and replace cylinder head gaskets (copper and asbestos). Tighten and safety cylinder head.

(4) Engine oil leaking from between piston and cylinder at the rear of the cylinder is caused by either a loose piston gasket nut, or worn, or damaged piston gaskets. In either case, the airplane mechanic can make the corrections.

(5) Engine oil leaking from around the front cone or at the rear of the barrel on a propeller installed on a Pratt and Whitney engine would cause the mechanic to remove the propeller to ascertain if the front cone packing washer is in place and in serviceable condition. To replace this washer requires removal of the snap ring, spacer, and front cone.

(6) Engine oil being thrown out the breather hole in the piston of a propeller installed on a Wright engine. The most probable cause for this condition is either a loose supply pipe packing nut or a damaged supply pipe packing. To correct this, remove cylinder cap and check condition of gasket and tightness of nut. Replace gasket if necessary.

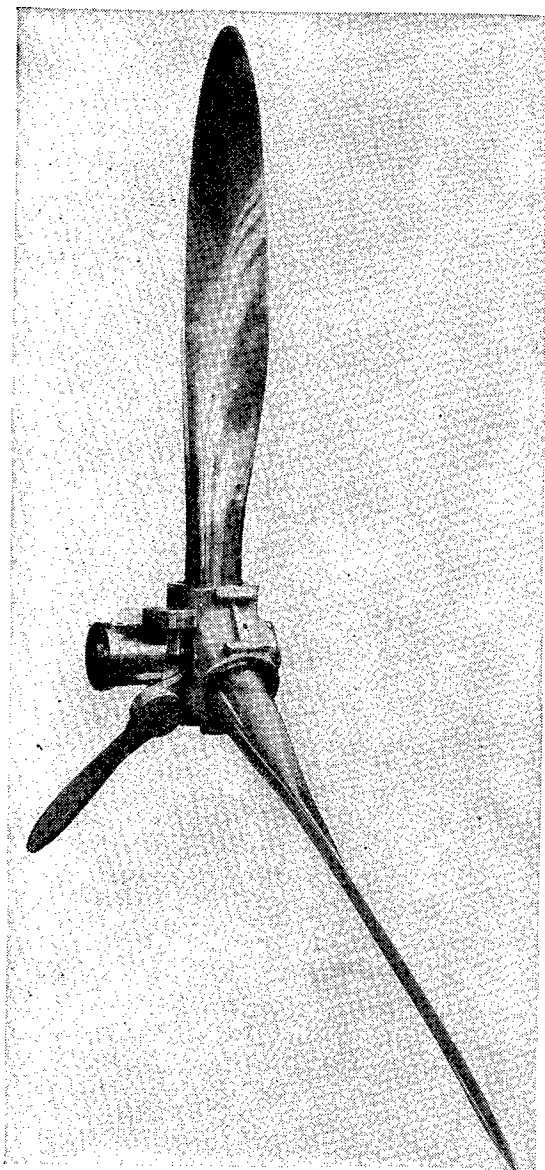


FIGURE 13.—Hamilton standard two-position propeller.

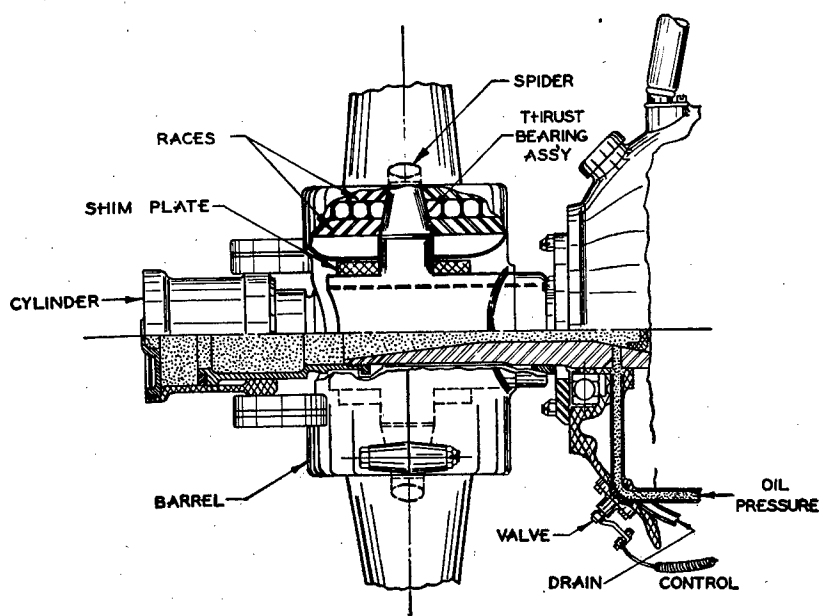


FIGURE 14.—Cross section of propeller hub.

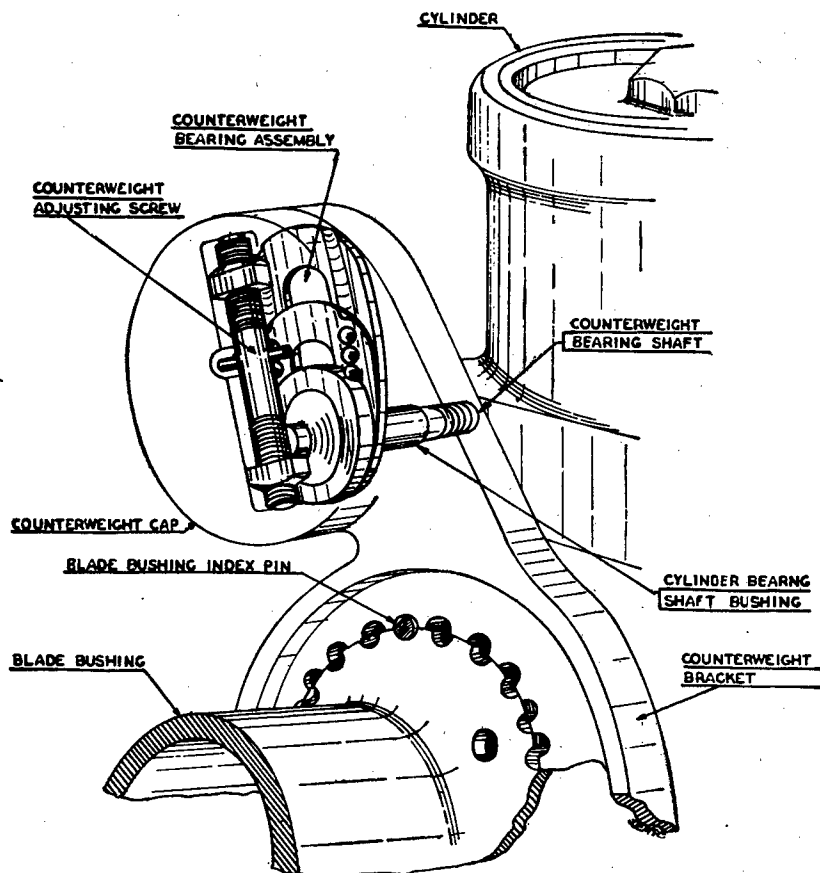


FIGURE 15.—Counterweight assembly.

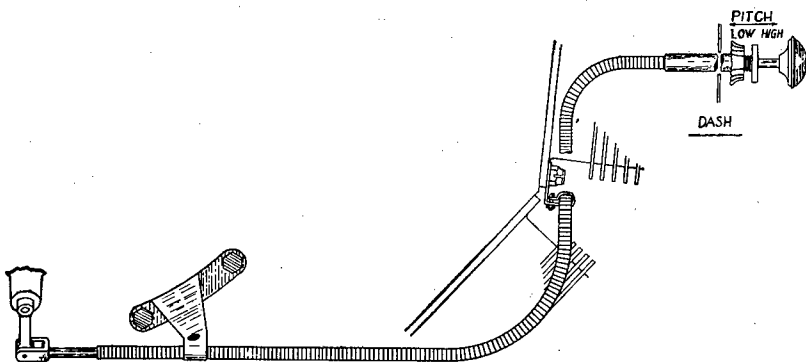


FIGURE 16.—Propeller control.

SECTION VI

HAMILTON STANDARD CONSTANT SPEED PROPELLER

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32. Principle of operation.—The Hamilton standard constant speed propeller (fig. 17) utilizes the same hydraulic principle of operation as the two-position controllable propeller, except that the action of a spring return assembly is added. This spring assembly, which is installed inside the propeller piston, is compressed when the propeller shifts to low pitch (high r. p. m.) thus aiding the operating force of the counterweights in returning the propeller to high pitch (low r. p. m.). The spring force is greatest in full low pitch, becoming less as the pitch shifts toward high pitch. About two-thirds of the way from full low pitch (high r. p. m.) to full high pitch (low r. p. m.) the spring force is discontinued and the counterweights alone provide the entire operating force. It is because of the increased angular travel of the counterweights and the slope of the counterweight cams that the spring return is needed with 20° propellers. In low pitch (high r. p. m.), the counterweights are closer to the axis of rotation of the hub than they are in low pitch (high r. p. m.) position of a two-position controllable (10° pitch range). Consequently for the same r. p. m. the centrifugal force on the 20° counterweights is less. Either heavier counterweights must be used or additional operating force provided in some other way to obtain responsive pitch changing. It is preferable to utilize the added force of the spring return assembly rather than to make the counterweights heavier. Due to the design requirements of the 20° pitch range propeller, the usual engine oil pressure is not great enough to shift the blades to low pitch (high r. p. m.) position and it is necessary to use a booster pump. This is incorporated in the Hamilton standard constant speed control. The pump takes oil from the engine lubricating system and raises its pressure to 180 to 200 pounds per square inch. A built-in relief valve regulates the pressure and returns all oil to the pump except what is actually required to shift the propeller pitch and take care of leakage at the transfer rings. Only a very small quantity of

oil is drawn from the engine, inasmuch as the propeller demands oil only when going to a lower pitch (higher r. p. m.) setting. The constant speed control takes the place of the three-way valve. It regulates the flow of oil to and from the propeller cylinder, automatically shifting the pitch so as to maintain constant r. p. m. The pilot can set the constant speed control to any r. p. m. within the operating range. The constant speed control shifts the propeller pitch as necessary to maintain this r. p. m. Under these conditions, the pilot does not directly control the pitch. However, provision is made so that he may discontinue the constant speed action and shift the propeller to positive high pitch in which case the propeller will remain in full high pitch (low r. p. m.) position. Except where a limiting r. p. m. stop has been installed on the constant speed unit, it is possible to move the controls to obtain positive low pitch. This would permit operation similar to that for a two-position propeller not having a constant speed control.

33. Description.—The description in paragraph 26 applies to the Hamilton standard constant speed propeller except as modified herein. The difference in construction is as follows:

a. Shim plates and laminated shims are used to obtain proper barrel fit of the hub assembly. Shim plates are made of self-lubricating material (oilite). Formica chafing strips are not used as the barrel is supported by micarata blocks. These shim plates are free to turn on the spider, no dowel pins being used. To insure a reasonably tight over-all fit of the blade assembly parts which are held between the spider and the barrel, laminated shims are peeled to the required thickness and placed between the oilite shim plates and the spider.

b. The piston is of steel. Care is taken in turning the threads at its base to insure their proper fit on the engine crankshaft. A shoulder is turned at the outer end of the piston on which gaskets fit. These gaskets form an oil tight surface between the cylinder and the piston and serve as a guide to the cylinder as it moves back and forth. A similar but smaller gasket is provided at the base of the piston to act as a seal between the piston and oil supply pipe. Several holes are bored radially through the base of the piston. These permit crankcase ventilation through the engine shaft. The same piston can be used for engines having other means of crankcase ventilation. Interchangeability is accomplished by the use of the proper engine shaft oil supply pipe adapters. A spring assembly fits inside the piston and is carried on a puller bolt attached to the cylinder head. When the cylinder moves outward to high r. p. m.

(low pitch), the springs are compressed, thus introducing additional force to help the counterweights return the pitch to low r. p. m. (high pitch).

c. Each counterweight bracket carries a counterweight bearing assembly which consists of a curved steel counterweight bearing race, a curved bearing retainer, and a circular steel cap race. The counterweight bearing race fits snugly into the cam slot of the counterweight bracket. The circular cap race has a ball seat on its outer face into which the ball seat of the bearing shaft fits. The retainer is held in place between the two races by means of the bearing shaft. When the bearing shaft is tightened in place, the fit of the counterweight bearing assembly should be such as to provide 0.002-inch to 0.003-inch clearance between the oilite thrust washer and the face of the counterweight bracket. To prevent bending of the counterweight bearing retainers and to generally improve the action of the counterweight bearings, a spacer is added to the assembly. The spacer maintains the alinement of the bearing retainer with respect to its inner and outer races. It provides a guide for the retainer, permitting it to work back and forth freely but preventing it from bending outward under the pull of centrifugal forces.

d. Grease retainers are provided to retain the grease inside the spider arms and blade cavities. They are made of leather and shaped on one side to fit the fillet at the base of the spider arm. The flat side of the retainer rests against the face of the blade bushing. The sides of the retainer are supported by a special coil spring.

34. Installation and removal.—a. Installation of the propeller is accomplished as follows:

- (1) Thoroughly clean out the inside of front portion of crankshaft. Remove screw plug from inside crankshaft.
- (2) On Wright engines, install oil supply pipe with gasket in feed line inside crankshaft. On Pratt and Whitney engines, install oil supply pipe and adapter inside end of crankshaft.
- (3) Install bronze rear cone on engine shaft against thrust nut and thread guard with sleeve over threaded end having splines of thread guard alined with those of the shaft.
- (4) See that the blades of the propeller are set in low r. p. m. (high pitch) position. Remove cylinder head lock wire and clamp nut lock wire installed in hexagon portion of cylinder head. Unscrew clamp nut and remove gasket and vernier lock plate (figs. 18 and 19). Unscrew cylinder head, using wrench furnished with propeller. Remove complete spring return assembly by unscrewing piston gasket nut. Remove piston. To remove piston, the propeller

is shifted toward the low pitch position in order to remove front cones from piston.

(5) Oil splines of crankshaft and hub and oil rear cone and cone seat.

(6) Aline spline and slide hub well back on shaft.

(7) Aline cylinder by means of blade beams on blades until proper cylinder alining bushing slides freely over sleeve and into cylinder.

(8) Remove cylinder alining bushing, sleeve, and thread guard.

(9) Check oil supply pipe packing nut for tightness and proper safety.

(10) Coat threads of piston with thread lubricant and insert piston and front cones. It will be necessary to shift the propeller pitch as given in paragraph 34.

(11) Having alined the cylinder, the piston will screw on easily unless the piston or shaft threads are damaged. If piston does not start on easily, check condition of these threads. The use of lapping compound on these threads is considered a dangerous practice.

(12) Insert proper wrench and tighten piston, using a bar 4 feet long. Apply a force at the end of the bar of approximately 175 pounds.

(13) Install complete spring assembly in piston and tighten down against piston gaskets. Use a wrench provided and a bar approximately 2 feet long.

(14) Place cylinder head gasket on cylinder head. A light coating of grease will hold this gasket in place.

(15) Screw cylinder head on cylinder. This should be tightened with wrench and bar used on spring assembly. As cylinder head is tightened, the clamp washer on splined spring puller bolt will enter guide on underside of cylinder head. The purpose of this guide is to help center the spring puller bolt.

(16) Lock cylinder head with its lock ring.

(17) Lock cylinder head to spring puller bolt by means of vernier lock plate. By turning vernier one cog at a time, a combination will be found which will allow the vernier to be pushed in place. The groove and ring on one side of the vernier are to facilitate its removal and should be toward the front.

(18) Place clamp nut gasket in cylinder head face.

(19) Tighten clamp nut on threaded end of spring puller bolt. A relatively short wrench should be used. The object is merely to hold the clamp washer on the spring puller bolt tightly against the cylinder head and provided an oil seal.

(20) Lock clamp nut with its lock wire.

(21) Check all lock wires and cotters.

b. The method of removing the propeller from the crankshaft is the reverse of installation procedure as follows:

(1) Move blades toward full low r. p. m. (high pitch) position to remove any compression of spring return assembly. It is important that this is done before removal of clamp nut. This will prevent the threads of the clamp nut from being stripped by the pulling force in the compressed spring return assembly.

(2) Remove clamp nut lock ring and unscrew clamp nut.

(3) Remove vernier lock plate and clamp nut gasket. Failure to remove vernier lock plate before attempting to unscrew cylinder head will result in serious damage to puller bolt.

(4) Remove cylinder head lock ring and unscrew cylinder head.

(5) Unscrew piston gasket nut and pull out with spring assembly.

(6) Remove two piston gaskets.

(7) Unscrew piston. Slide propeller slowly forward on engine shaft and remove. Take care not to damage engine shaft threads.

35. Lubrication.—Before the propeller assembly is installed on the engine, or if the propeller is assembled and placed in storage, the hub spider is filled and the counterweight shaft bearings thoroughly coated with grease.

a. At the specified periodic inspection, the counterweight shaft bearings are coated with grease, the purpose being to prevent corrosion by means of a protective film of grease more than to actually lubricate the moving parts. The counterweight shaft bearings can be lubricated through the slot in the counterweight without removing the cap. If the counterweight cap is removed, care is exercised to insure that the location of the stop nuts on the adjusting screw is not disturbed as any change in the position of the stop nuts will result in a change of the blade angle.

b. Lubricate hub spider through lubricator fittings provided. Since these propellers have grease retainers which prevent the grease inside the spider arms and blade cavities from leaking out past the shim plates, there should be no trace of lubricant at the barrel ends. If grease does appear at this point, it is an indication that a grease retainer is not functioning properly and should be replaced. However a check should be made to insure that the grease is not surplus grease which has been forced into the hub shell during the lubricating periods.

36. Propeller controls.—a. The governor is a device used in conjunction with the Hamilton standard controllable propeller to automatically maintain the engine r. p. m. constant at any speed selected by the pilot (fig. 20). It does this by changing the blade angles to

meet new conditions of altitude, airplane attitude, and throttle setting. The control permits the independent setting of engine power and engine speed. This means that with the specified propeller it will permit the engine to develop any selected power at any selected speed and will maintain that engine power and speed throughout all flight conditions until the pilot readjusts the governor controls for some new operating r. p. m.

b. The only limits to this are those imposed by the governing range of the governor and the mechanical stops in the propeller counterweights. Under conditions demanding a lower or higher blade angle than is possible within the limitation of the propeller itself, the governor, although trying to hold the r. p. m. constant, is unable to do so because the blades are prevented from assuming a lower or higher angle by their counterweight stops. Under these conditions, the propeller will act as a fixed pitch propeller and the throttle will govern r. p. m. as well as manifold pressure.

c. The governor is an independent unit whose only function is to regulate the flow of oil to and from the propeller. Since the magnitude of the blade angles of this type of controllable propeller depends on the position of the cylinder, which in turn depends on the volume of oil in the cylinder, it is apparent that a mechanism which automatically permits the flow of oil under pressure to the propeller cylinder and the drainage of oil from the cylinder in a rapid cycle will enable the blades to assume an indefinite number of angle settings.

d. Horsepower varies with r. p. m. and manifold pressure. The r. p. m. is controlled, within the limits previously mentioned, by the governor; the manifold pressure is regulated by the throttle.

e. Because it is the governor rather than the throttle which controls the engine r. p. m., it is possible to use a larger range between the minimum and maximum angle limits of the propeller blades and consequently it is possible to obtain higher horsepower for take-off and power descent. With the two-position controllable propeller, the minimum blade angle must be high enough to prevent overspeeding of the engine during take-off and climb; the maximum blade angle must be such as to permit cruising at the specified conditions of r. p. m. and manifold pressure at altitude. The factors limiting the blade angle range for a constant speed propeller are, that in case of failure of the mechanism, the minimum angle shall be high enough to permit sustained flight without overspeeding the engine, and the maximum angle shall be low enough to permit flight without increasing the manifold pressure beyond the engine manufacturer's specified limits. The lower minimum angle permits better take-off characteristics since it allows the full horsepower of the engine to be developed

early in the take-off. The higher maximum angle permits power descents from altitude without overspeeding of the engine.

f. The governor is a self-contained assembly which is mounted on one of the engine accessory pads or on a specially built pad on the nose of the engine. The unit's drive is coupled to the engine by a suitable gear ratio to insure that its operating range coincides with the engine r. p. m. range. A small gear booster pump is incorporated in the unit. This pump takes oil from the engine lubricating system and increases its pressure to 180-200 pounds. The oil pressure is regulated by a relief valve through which all oil not actually required to shift the propeller angle is returned to the inlet side of the pump. Only a small quantity of oil is drawn from the engine system, inasmuch as the propeller demands oil only when going to a lower angle or to replace that lost at the shaft transfer rings. Governing action is obtained by flyball forces working against a speeder spring. The metering of oil to and from the propeller cylinder is dependent on the degree of balance which exists between these forces.

g. Engine oil enters the governor unit through the base and is led to the low pressure side of the booster gear pump. As the oil passes through the pump, its pressure is controlled to 180-200 pounds. From the high pressure side of the pump, the oil is led past the relief valve and into the hollow drive gear shaft through ports located in the upper portion of the shaft. Whether this pressure oil is permitted to go through the lower propeller ports of the drive gear shaft and out to the propeller or whether it will circulate through the relief valve, the hollow idler gear shaft, and return to the inlet side of the booster pump, depends upon the position of the pilot valve with relation to the propeller ports. The position of the pilot valve depends in turn upon the relation of the centrifugal force generated by the flyballs (fig. 21) to the force exerted by the compression of the speeder spring. Under theoretically stable conditions of flight, these two forces are balanced and the pilot valve covers the propeller ports in the drive shaft. If the throttle setting is changed, or if the altitude or attitude of the airplane is altered, or if the pilot desires a different engine speed and changes the constant speed cockpit control setting, the balanced condition which existed between the forces of the flyball and the speeder spring will be disturbed. Any unbalance in the flyball speeder spring forces will allow one of the two forces to override the other and cause the pilot valve to open the propeller ports in the drive gear shaft, either to the position which allows the high pressure oil in the shaft to flow to the propeller cylinder or to the position which allows the oil in the propeller cylinder to drain into the engine sump.

h. Figure 22 indicates three states of balance and unbalance for three different operating conditions.

(1) The first, "On speed," is the condition which exists when the factors in flight are constant; that is, the airplane is flying level at a selected r. p. m. and manifold pressure. There is no tendency for any change in the desired engine r. p. m. The flyballs are turning at a constant speed and exerting a constant force against the balancing compression of the speeder spring. The propeller ports in the drive gear shaft are just closed by the pilot valve. Since no oil is flowing either to or from the propeller cylinder, the angle of the blades is being held fixed. The arrows show that oil is passing through the booster pump and being by-passed through the relief valve to the inlet side of the pump.

(2) The second, "Underspeed," shows what happens when the flyball speeder spring system is thrown into a state of unbalance caused by a small decrease in engine r. p. m. Such a case occurs momentarily when the airplane is pulled up in a steep climb or when the throttle is suddenly moved toward the closed position. Since the flyballs are driven at a definite speed with relation to the engine r. p. m., their rotation will decrease with the decreasing engine r. p. m. This will cause a lessening of their centrifugal force which will permit the speeder spring to override the flyballs and force the pilot valve downward. This movement of the pilot valve opens the propeller ports to the high pressure oil. This oil enters the propeller cylinder, moving the blades to a lower angle and permitting the engine to regain and hold its r. p. m.'s at the desired value.

(3) The third, "Overspeed," indicates what happens when the engine r. p. m. tend to increase. Such a condition occurs when the airplane is nosed down or when the throttle setting is increased. With the increase in engine speed, there is an increase in the flyball rotational speed and a corresponding increase in centrifugal force. The flyball speeder spring system is thrown out of balance as the force generated by the flyballs overrides the speeder spring load. In moving outward, the flyballs lift the pilot valve and open the propeller ports to the drain position. Oil flows from the propeller cylinder permitting the blades to assume a higher angle and thus bring the engine r. p. m. back to the desired figure.

(4) Under actual operating conditions, the pilot valve speeder spring system is rarely in the position indicated by the "On speed." Due to more or less constant changes in altitude, bumpy air, and variations in engine hp. requirements due to maneuvers of the airplane, the governor is continually operating to make corrections in propeller

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blade angles necessary to maintain the engine r. p. m. constant. It is rarely possible to have the balanced condition indicated in the "On speed," as there is a continual leakage of oil in the engine transfer rings. Since the angle of the propeller blades is regulated by the volume and pressure of oil in the propeller cylinder, it is necessary to supply an additional amount of oil equal to that lost through the transfers in order to hold the blades at a desired angle. To accomplish this, the propeller ports in the governor drive shaft must be "cracked" open. The extent of this opening depends on the amount of transfer ring leakage.

i. The unit is removed as follows:

- (1) Disconnect cockpit control from unit.
- (2) On units having external piping, disconnect pipe connections.
- (3) Remove mounting stud nuts.
- (4) Remove governor.
- (5) On some installations, the fit is so close that it is impossible to raise the unit high enough to clear the mounting studs. In these cases, the usual procedure is to remove the cap section of the unit's case. This is done by removing the nuts and palnuts which fasten the cap section to the body section. The cap section may now be lifted from the unit. As the cap section is lifted, the control shaft should be turned counterclockwise looking at the face of the pulley. The purpose of this is to disengage the speeder spring adjusting rack and the control shaft. If the cap section is removed with the pilot valve spring collar assembly, it cannot be raised high enough to pull the pilot valve out of the drive gear shaft and still keep these two parts in alinement. This alinement is kept in order to prevent side loads which might bend the spring collar spindle. If it is necessary to remove a unit between propeller overhaul periods temporarily, the control is moved to full decrease r. p. m. position, the pulley or lever and shaft are marked and removed from control shaft. This will permit reinstallation in exactly the same position and will facilitate the adjustment of the control system.

j. The installation of the governor and cockpit controls will be in accordance with the installation drawings covering the particular airplane except that the following precautions are taken:

- (1) The propeller governors are checked to insure their proper functioning before installing on an engine.
- (2) To install a governor, remove cover from surface on which governor is to be mounted. Then set governor in position, checking fit of governor circular lining boss. In some cases it is found that this boss is slightly larger than the opening on the engine into which

it fits. If this condition exists, further investigation is made to determine which part is to be reworked.

(3) The governor securing nuts are then screwed on the mounting studs and run down finger tight. Remove governor head and check backlash and freedom of movement while tightening governor securing nuts. It is essential to tighten these nuts down evenly. The securing nuts are not to be drawn down excessively tight as this may cause displacement of the gasket material in the vicinity of the mounting studs and result in warping the governor base. In some cases it has been noted that the governors are susceptible to binding after having the nuts tightened. This condition can normally be relieved by slacking off slightly one or more nuts. The nut or nuts causing the difficulty can be determined by trial.

(4) Another precaution which is advisable is that during the tightening of the securing nuts the propeller shaft is rotated to at least three positions, checking the governor for backlash and freedom of movement at each point.

(5) It is good practice to check the governors for freedom of movement before installing, as a few cases have been reported where cold temperatures and improper fit of bearings have caused the governors to bind. Therefore, any binding or drag in the governor is thoroughly investigated before attempting to install it on an engine.

(6) If binding or drag is experienced with two or more governors, it is advisable to check the engine drive parts. Engines equipped with the governor drive in the nose sections can be checked by removing the nose section and installing a governor on it. If the governor binds, the vertical drive gear in the nose section is checked for freedom by rotating it back and forth to determine the backlash. The alinement of the governor drive spline in the vertical drive gear is determined by working the vertical drive gear up and down. Both these checks are made at several different points by removing the governor and turning the vertical drive shaft to a new position and then reinstalling the governor.

(7) The primary precaution is to make sure the governor turns freely when assembled to its drive on the engine.

k. The angular range required at the constant speed unit to give rated r. p. m. at one end and positive high angle at the other is only a part of the unit's total angular range. Before flying, it is important that the control system between the governor and the cockpit is adjusted to set the unit for rated r. p. m.

l. For trial setting, place cockpit lever in extreme rear position. Turn pulley or lever attached to governor control shaft in a clock-

wise direction until the rack bottoms in the cap. Connect control cable or rod extending from cockpit control lever to pulley or lever attached to governor shaft. Loosen increase r. p. m. stop and shift away from governor. Start engine and operate on ground until desired take-off r. p. m. is obtained, moving governor lever in cockpit forward. Stop engine, exercising care to insure that setting of governor lever in cockpit is not disturbed. Adjust increase r. p. m. stop toward governor until it bottoms against pulley stop or lever. Make flight test to insure that governor is adjusted properly. If during flight, the rated r. p. m. cannot be obtained or if excessive r. p. m. is encountered, readjustment of the controls is necessary. To increase the r. p. m., the governor stop is loosened and shifted away from the governor pulley or lever. Make another trial flight adjusting cockpit control lever until rated r. p. m. is obtained, marking the quadrant at this position. After landing and stopping engine, adjust cockpit control lever to marking on the quadrant and reset governor stop. To decrease the r. p. m., adjust cockpit control during trial flight marking quadrant, and after landing and stopping engine, adjust cockpit control to marking and governor stop until it firmly bottoms against governor control lever or pulley.

37. Operation.—*a.* Prior to starting an engine equipped with a Hamilton standard constant speed propeller, the propeller control is placed in "positive high pitch" position. After starting, the engine is run for at least 1 minute with the control in this position.

b. The propeller control is shifted to low pitch (high r. p. m.) position for the warm-up. The warm-up must be at the required r. p. m. and to the specified temperature as outlined in operating instructions for the particular type of engine.

c. The propeller cockpit control is moved to the "increase" r. p. m. position for take-off and climb. As the airplane increases from zero speed at the start of the take-off toward flying speed, the engine r. p. m. will increase until it reaches the amount for which the high r. p. m. limit stop has been set. From this point on, the r. p. m. is held constant by the governing action of the unit. Soon after take-off, it is desirable to reduce both the manifold pressure and the r. p. m. The logical sequence is to reduce the manifold pressure first and then the r. p. m. All movements of the throttle and propeller cockpit control are done slowly.

d. Once the r. p. m. has been brought to the desired tachometer reading for normal level flight, it is held constant by the governor. Any change in the cruising r. p. m., or manifold pressure is made by first adjusting the propeller control to the new value and then

the manifold pressure. This is especially true of multiengine installations. Once the propellers have been brought into synchronization, the manifold pressure may be altered without causing any change in r. p. m. or necessitating resynchronizing.

e. If the governor is operating satisfactorily, it will permit a power descent without overspeeding the engine. The unit compensates for the increased airspeed of the descent by increasing the propeller blade angles. If the descent is too rapid or is being made from a high altitude, the maximum blade angle limit of the blades is not sufficient to hold the r. p. m. constant. When this happens, the r. p. m. is responsive to any change in the throttle setting.

f. As the manifold pressure and airspeed are reduced in the approach for a landing, the r. p. m. is held constant by the governor and the propeller is moved to a lower blade angle. When conditions of manifold pressure and airspeed are such as to require a blade angle equal to the minimum angle stops in the counterweights, the blades will be against the minimum angle stops in order to maintain the r. p. m. constant, and the governing action will be unable to operate them to a lower angle.

(1) Some pilots consider it advisable to set the governor control for maximum r. p. m. during the approach in order to have full horsepower available in case of emergency. If the governor control is set for this higher r. p. m. early in the approach when the blades have not yet reached their minimum angle stops, the r. p. m. will increase to unsafe limits. If, however, the governor control is not readjusted for the take-off r. p. m. until the approach is almost completed, the blades will be against, or very near, their minimum angle stops and there will be little if any change in r. p. m. In case of emergency, both throttle and propeller controls can be moved to take-off positions.

(2) Most pilots prefer to feel the airplane respond immediately when they give short bursts of the throttle during approach. By making the approach under a little power and having the governor control set at or near cruising r. p. m., this result will be obtained.

(3) Although the governor responds quickly to any change in throttle setting, a sudden and large increase in the throttle setting will cause a momentary overspeeding of the engine until the blades become adjusted to absorb the increased power. If during approach an emergency demanding full power should arise, the sudden advancing of the throttle will cause momentary overspeeding of the engine beyond the r. p. m. for which the governor is adjusted. This

temporary increase in engine speed acts as an emergency power reserve reserve.

g. For the purpose of preventing exposure and corrosion of the propeller piston on idle engines, the propeller control is shifted to "positive high pitch" prior to stopping the engine.

38. Inspection and inspection maintenance.—*a.* The range of operation of the propeller is checked as follows:

(1) After the engine is warmed up to specified operating temperature, set throttle to give approximately 1,600 r. p. m. with propeller in low pitch position.

(2) Move propeller control to "positive high pitch" and observe corresponding pitch change and decrease in engine r. p. m. When no further decrease is indicated on the tachometer, the propeller is in full high pitch (low r. p. m.) position.

(3) Move propeller control to "take-off" r. p. m. position and observe the corresponding pitch change and increase in engine r. p. m. When no further increase is indicated on the tachometer, the propeller is in full low pitch (high r. p. m.) position.

(4) Move propeller control in constant speed position. Any movement of the throttle within limitations is not indicated by an increase or decrease in engine r. p. m. The propeller is then functioning in the constant speed position.

b. After the daily or preflight warm-up, an inspection is made of the propeller and governor for oil leaks. Special attention should be paid to the mounting base of the governor. Any leaks noticed are corrected before flight. The more probable cause for oil leaks are—

- (1) Cylinder head; loose cylinder head or damaged gasket.
- (2) Base of cylinder; damaged or worn piston gaskets.
- (3) Grease leaking from around blade; grease retainers are worn or improperly installed.

(4) Base of governor; gasket damaged or loose mounting stud nuts.

c. The propeller controls are inspected for full movement from cockpit control to governor. Cables are inspected for size and tension. Torque rods and bell cranks are inspected for freedom of movement. Any indication of binding or interference is corrected before flight.

d. The procedure for checking the piston of a Hamilton standard constant speed propeller is as follows:

- (1) With the aid of blade beams, move propeller into full high pitch (low r. p. m.) position.
- (2) Remove clamp nut lock wire and clamp nut.
- (3) Remove vernier lock plate.
- (4) Remove cylinder head lock wire and cylinder head.

- (5) Unscrew piston gasket nut and remove spring return assembly.
- (6) Insert proper wrench into piston. With a 4-foot bar, one man weighing approximately 175 pounds pulling on the end of the bar is sufficient to check the piston for looseness. A steady pull on the end of the bar without jerking is recommended to make the check.
- (7) Install spring return assembly and tighten piston gasket nut.
- (8) Install cylinder head and cylinder head lock wire.
- (9) Install vernier lock plate, clamp nut, and clamp nut lock wire.
- e. When cleaning and lubricating the exposed portion of the piston of a Hamilton standard constant speed propeller having a spring return assembly, the following procedure applies:
 - (1) With the aid of blade beams, move propeller into full high pitch (low r. p. m.) position.
 - (2) Remove clamp nut lock wire, clamp nut, and vernier lock plate.
 - (3) Remove cylinder head lock wire and cylinder head.
 - (4) Unscrew piston gasket nut and remove spring return assembly.
 - (5) By using blade beams, move propeller into full low pitch (high r. p. m.) position.
 - (6) Clean exposed portion of piston with approved cleaning fluid. Remove all corrosion and defects by careful handstoning and by the use of crocus cloth.
 - (7) Lubricate piston with clean engine oil.
 - (8) Move propeller into full high pitch (low r. p. m.) position.
 - (9) Install spring return and tighten piston gasket nut.
 - (10) Install cylinder head and cylinder head lock wire.
 - (11) Install vernier lock plate, clamp nut, and clamp nut lock wire.
- f. The problems and corrections as listed in section V are applicable to this type of propeller. Other maintenance problems and their corrections are as follows:
 - (1) When installing a governor on an engine, trouble may be encountered in synchronizing the propeller with the governor and controls. In such case, Air Corps Technical Orders on this equipment should be consulted.
 - (2) It must be remembered that the spring return is compressed when the propeller is in low pitch (high r. p. m.) position. In event it is necessary to have the propeller in low pitch so as to be able to perform the required maintenance on the piston, the engine should be stopped with the propeller in high pitch (low r. p. m.) position. Remove the spring return, and with the aid of blade beams, the propeller is placed in low pitch (high r. p. m.) position. Never attempt to remove the spring return unless the propeller is in full high pitch position.

(3) During operation, it is sometimes difficult to maintain a constant r. p. m. This has all the symptoms of the propeller control "creeping" and may be due to the cable "stretching." Readjust the tension on the cable and check all mountings.

(4) Constant speed propellers without the spring return may seem slow and sluggish in return to high pitch (low r. p. m.) position. Probably the engine r. p. m. is not sufficiently high with correspondingly high centrifugal force to return the propeller to high pitch. Excessive blade friction may be the cause. The adjustment in and to the governor should be checked if neither of the above corrections help the condition.

(5) With the propeller control in the take-off position (low pitch), the propeller returns toward the high pitch position at full throttle. Check linkage between governor control shaft and cock-pit and ascertain if governor control shaft has its full movement of travel.

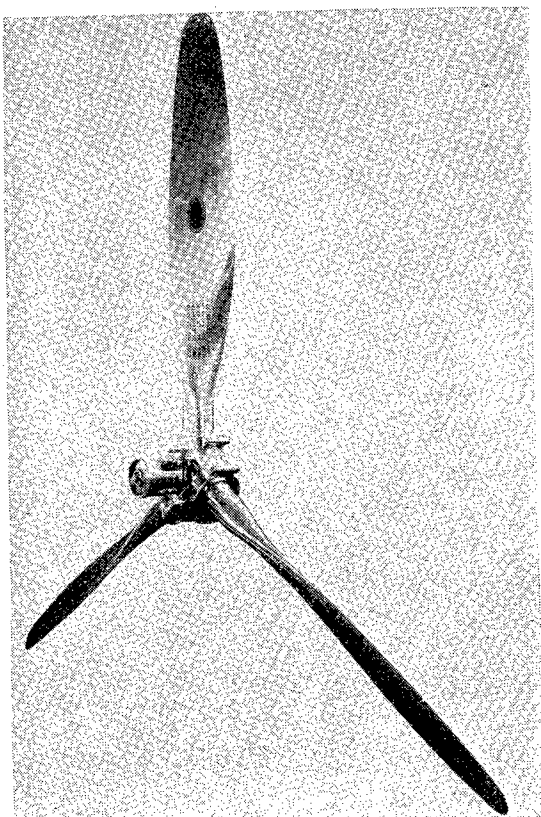


FIGURE 17.—Hamilton standard constant speed propeller.

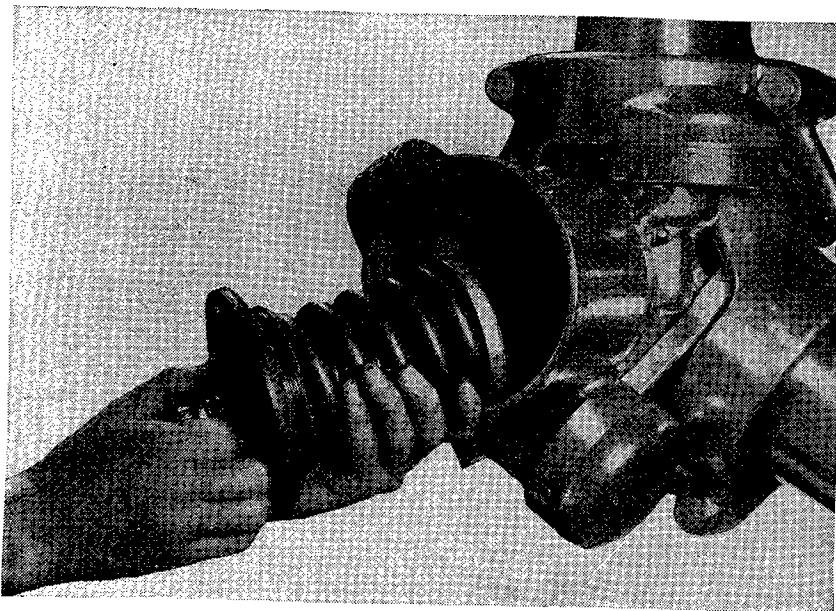


FIGURE 18.—Removal of spring return assembly.

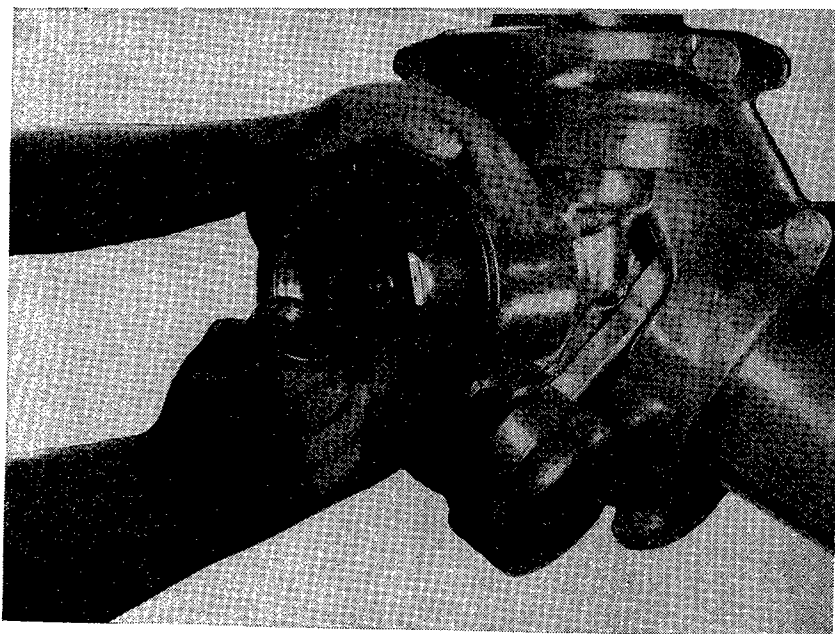


FIGURE 19.—Removal of vernier lock plate and clamp nut.

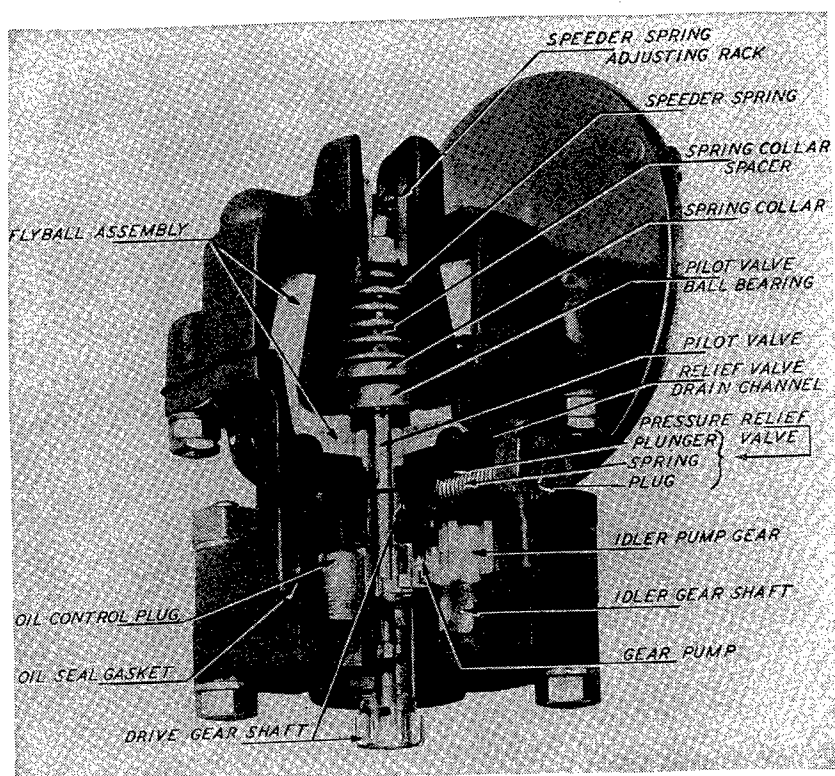


FIGURE 20.—Governor assembly.

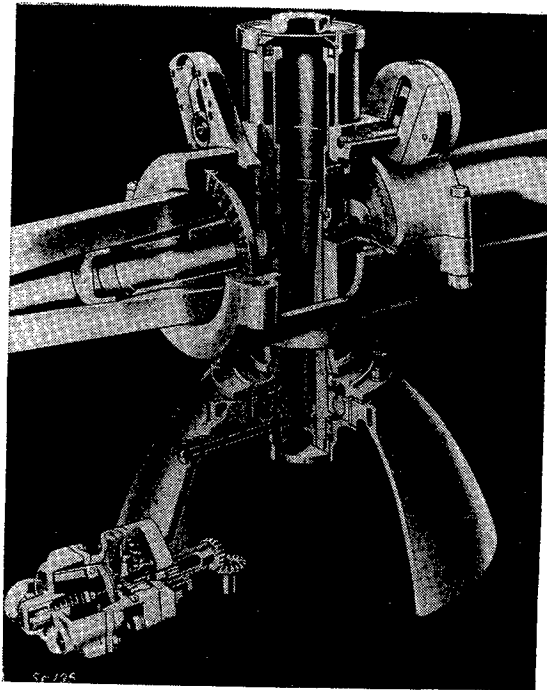
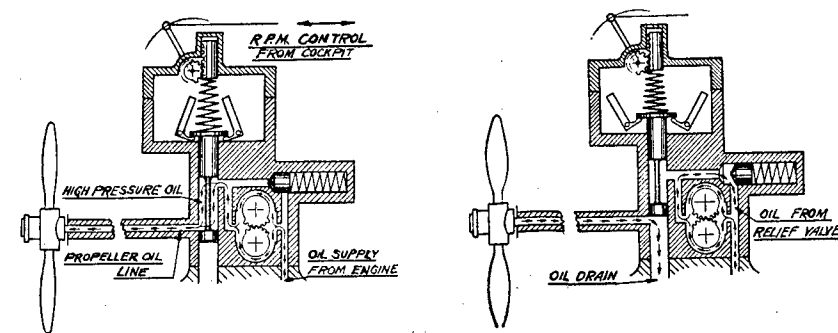
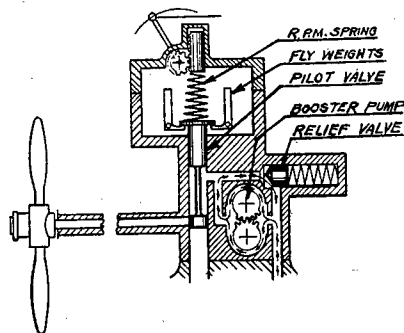


FIGURE 21.—Oil system of governor and propeller.

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- ① "Underspeed." High pressure oil enters propeller oil line to decrease pitch. ② "Overspeed." Oil drains from propeller to increase pitch.



- ③ "On speed." Pilot valve closes propeller line to maintain pitch.

FIGURE 22.—Governor operating principle.

SECTION VII

HAMILTON STANDARD HYDROMATIC PROPELLER

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39. Principle of operation.—*a.* The centrifugal twisting moment which is always present in a rotating propeller is a very powerful force tending to turn the blades toward low pitch position. In the hydromatic propeller, this blade twisting moment is utilized as the operating force to change pitch toward lower blade angles; while oil pressure acting on a piston in a cylinder opposes the blade twisting moment and provides the operating force to change pitch toward higher blade

angles. This direct use of the natural forces eliminates the need for counterweights and simplifies the mechanism. The internal mechanism of this propeller is shown in figure 23.

b. The piston is connected to the blades through cylindrical cams and gears so that the blades change pitch as the piston moves from one end of the cylinder to the other. The oil pressure which provides the operating force toward high pitch is fed into the inboard end of the cylinder where it forces the piston outward and increases the pitch in proportion to the amount of oil admitted. When the piston is in close to the hub, the pitch is low, and when it is out from the hub, the pitch is high. In the extreme outward position of the piston the blades are full feathered.

c. The piston cylinder assembly is so arranged that the piston can be moved inward by oil pressure as well as outward. This is necessary for unfeathering because there is no blade twisting moment available when the propeller is feathered and the engine stopped. It is also desirable to assist the blade twisting moment when the r. p. m. is low during warm-up and taxiing.

d. For normal operation, oil from the engine lubricating system is fed through the crankshaft directly into the outboard end of the cylinder, thereby maintaining constant engine pressure on the piston in the direction of low pitch. Oil from the constant speed control governor under sufficient pressure to overcome both the blade twisting moment and the engine oil pressure is fed into the inboard end of the cylinder. The constant speed control admits oil to the cylinder or drains oil from it, automatically increasing or decreasing the pitch as necessary to allow the engine to run at constant r. p. m. regardless of the altitude of the airplane.

e. For feathering and unfeathering, an auxiliary oil pressure supply is retained which must be independent of the engine, due to the fact that feathering causes the engine to stop running. This oil is fed into the propeller through a check valve in the base of the constant speed control governor. When the auxiliary oil pressure is applied, the transfer valve automatically cuts out the constant speed control and directs the oil into the propeller.

f. To feather, the auxiliary oil is allowed to flow into the inboard end of the cylinder until the piston has moved to its extreme outward position where the blades are turned to full feathering. Thereupon the engine stops rotating and the propeller remains in the full feathering position of its own accord without need for further oil pressure. During the feathering operation, the oil in the outboard end of the cylinder flows back through the engine lubricating system and leaks

past the engine bearing into the sump where it is scavenged in the normal manner.

g. To unfeather, that is, to return the propeller to normal operation, it is necessary to again apply the auxiliary oil pressure, but this time allow it to build up sufficiently to actuate the distributor valve which is in the propeller mechanism. This valve, which is designed to operate only under pressure appreciably greater than that required for feathering, cannot open except when the propeller is in full feathering position and then only when the operator purposely allows the auxiliary oil pressure to increase to the predetermined amount.

h. When this pressure is reached, the distributor valve shuts off the oil passage leading to the inboard end of the cylinder and directs the oil through another passage to the outboard end of the cylinder. At the same time, the distributor valve changes the connection of the engine lubricating system from the outboard end of the cylinder to the inboard end. The auxiliary oil pressure in the outboard end of the cylinder moves the piston back toward the hub, changing the position of the blades from full feathering to a lower pitch. As the piston moves inward, the oil in the inboard end of the cylinder flows back through the engine lubricating system and into the sump.

i. As soon as the propeller shifts from full feathering, it commences to windmill due to the forward velocity of the airplane, and the oil in the sump is immediately scavenged before any great quantity can accumulate. When the windmilling reaches the desired speed for starting the engine, about 800 r. p. m., the auxiliary oil pressure is discontinued and the distributor valve assumes its normal position. The engine is then started and its r. p. m. is governed by the constant speed control which automatically cuts in as the auxiliary oil pressure is discontinued.

j. To summarize, the principle of operation of the hydromatic propeller is as follows: first, three fundamental forces are used to control the propeller; the twisting moment on the blades due to centrifugal force, engine oil under normal operating pressure, and engine oil under boosted pressure from the governor. The necessary balance between these control forces is maintained by the propeller governor, which in addition to boosting the engine oil pressure, meters to or drains from the propeller the quantity of oil required to maintain the proper blade angle for constant speed operation. Second, to feather the blades, an auxiliary pressure supply system is necessary. This consists essentially of an independent oil supply with provision for manual control by the pilot to provide 400 pounds pressure for feathering and 600 pounds for unfeathering. Figure 24 shows the control forces of a Hamilton standard hydromatic propeller.

40. Description.—*a.* The hub and blade assembly consists of three major parts; the spider, barrel, and blades. The spider may be considered as the foundation for the entire propeller. Its central bore is splined to fit the engine shaft and it is through these splines that the engine torque is transmitted to the propeller. It is equipped at either end with an accurately ground cone seat, and at its outer end, provision is made for the propeller retaining nut and front cone, by means of which the spider is attached rigidly to the engine shaft. Integral spider arms with two bearings on each arm support the blades, taking the great part of the thrust and torque loads from the blades.

b. The barrel is made from a steel forging, heat-treated. The shoulders of the barrel carry the centrifugal loads and provisions are made for the blade packings for oil tightness. It is supported on the spider by means of phenolic blocks located between the spider arms.

c. The blades used with the hydromatic propeller are identical in basic design with those in the Hamilton standard controllable propeller. They differ in slight detail at the inner end and are not interchangeable between the two propeller types. The blades are manufactured from aluminum alloy forgings and are of semihollow construction. The shank incorporates an internal aluminum bronze bushing which supports the blade on the spider arm. Machined on the outer periphery of the shank is a large radius which takes up the centrifugal force.

d. The dome is machined from an aluminum alloy forging. It acts as a case for the cam operating mechanism and as a cylinder for the piston. The outer surface also serves as a spinner. The assembly comprises the pitch changing mechanism by means of which oil forces on a double acting piston are translated into blade twisting moments. It consists of four major parts; two cylindrical coaxial forged steel cams, a double walled piston, and a dome cylinder which serves also as a housing for the entire unit. The piston and cylinder are machined from aluminum alloy forgings. When the dome unit is installed in the hub assembly, the outer or stationary cam becomes rigidly fixed in the barrel and provides support for the remaining parts of the dome unit. The inner or rotating cam, with which the main drive gear is integral, is supported within the stationary cam by means of ball bearings which take the gear reactions and piston oil forces. The piston motion is transmitted to the rotating cam by means of four sets of cam rollers carried on shafts supported by inner and outer walls of the piston.

e. The distributor valve housing is an aluminum alloy casting provided with cored passages for the operating pressure. A steel sleeve, shrunk into the central bore of the housing, contains ports

which align with oil passages in the housing. During constant speed operation of the propeller, it provides a passage through which engine oil boosted in pressure and metered by the governor is led to or from the inboard side of the propeller piston, and a passage through which oil under engine pressure is conducted to or from the outboard end of the cylinder. During feathering, the same two passages provide means for delivering high pressure oil to the inboard side of the piston and a means of conducting oil from the outboard end of the cylinder to the engine lubricating system. Thus, during constant speed operation or feathering, there is no movement of the distributor valve and the assembly merely provides passages through which oil may flow to and from the cylinder. In unfeathering, the function of the distributor valve is to reverse the above-mentioned passages. The high pressure oil from the auxiliary system is then led in the outboard side of the piston, and the inboard end is connected to the engine lubricating system, thus reversing the pressure differential and moving the piston toward the inboard end of the cylinder in order to unfeather the blades.

41. Installation and removal.—*a.* The provisions as outlined in section IX are followed in preparing the crankshaft for installation. The manner of installing the propeller is as follows:

- (1) Install propeller on crankshaft, sliding it back only far enough at first to engage the threads of propeller retaining nut with those of the shaft. The retaining nut and attaching parts are shown in figure 25.
- (2) With the aid of blade beams, turn blades to the feathered position, making sure that each blade is against the 90° or 88° stop pin.
- (3) Tighten propeller retaining nut on crankshaft using wrenches provided and a bar approximately 3 feet long. Apply a force of approximately 180 pounds at the end of the bar, and while the force is being maintained, rap the bar once close to the wrench with a hammer weighing not more than 2½ pounds. Determine if one of the locking slots in the nut is in alignment with one of the holes in the engine shaft. If not, repeat tightening procedure until one slot and hole are in alignment. Spacing of the slots in the nut is such that alignment of a slot and hole will occur each 5° of rotation.
- (4) Determine that the 1/32-inch copper gasket is in place against adapter flange, inside propeller shaft.
- (5) Check valve housing oil transfer plate on base of distributor valve assembly to be sure that it is properly in place with the 1/32-inch copper gasket between it and the valve housing. The oil transfer plate for use with engines which breathe through the pro-

propeller shaft has a 1¼-inch hole through its center to allow engine breathing. On the plate for use with engines which do not breathe through the propeller shaft, the hole in the center does not go through the plate but connects with the dome oil pressure line in the side of the valve housing.

(6) Lubricate threads of valve assembly, screw into shaft, and tighten with a 12-inch bar, applying a force of about 100 pounds at end of bar and striking bar one medium blow with a hammer weighing not more than 2½ pounds. If locking slots in valve housing are not alined with holes in crankshaft, repeat tightening operation until slots and holes are in alinement. Under no conditions will the valve housing be backed off even slightly in order to obtain slot and hole alinement. If alinement cannot be obtained, a new gasket will be used or the original gasket lapped.

(7) Install locking ring with pin through retaining nut slot, crankshaft hole, and into valve housing slot. Snap locking ring into position in groove provided for it in retaining nut.

(8) Before installing dome assembly on propeller, check low and high pitch adjustments to see if they are set at the correct angle.

(9) On propellers for engines which breathe through the propeller shaft, remove breather cup, breather tube nut, lock wire, nut, and seal from front end of dome assembly.

(10) Make certain that dome and barrel oil seal is properly installed in groove at the rear end of dome assembly. When installing dome assembly, it is absolutely essential that cam gear in dome be meshed with blade gear segments in proper angular relationship.

(11) Move piston in dome assembly into extreme forward 90° position. This position will be reached when the cam gear stop lugs are against the high pitch stop lugs.

(12) With blades still against the 90° stop pins, slide dome assembly over the end of valve assembly, making sure that the four piston rings on valve assembly enter properly into sleeve inside piston. Turn dome in a counterclockwise direction until dowel screws in base of dome assembly engage with alining holes in barrel shelf. The dome assembly is installed so that arrows stamped on dome and hub shelf are alined. The blade gears and cam gears, and also dome assembly locating screws and holes, are now in proper alinement, and the dome assembly is shoved, without turning, into the barrel. On engines which breathe through the crankshaft, make sure breather tube on front end of valve assembly is properly started into hole in front end of dome. The dome may now be rapped with a rawhide mallet in order to insure proper seating in

the barrel. Turning dome assembly in a clockwise direction in order to aline dowel screws and holes is to be avoided, as this will tend to move stop lugs on rotating cam away from the 90° position, thus allowing gears to mesh incorrectly.

(13) Tighten dome retaining nut in a manner similar to that described for tightening propeller retaining nut, applying a force of approximately 180 pounds at a 4-foot radius. With dome assembly properly seated in the barrel, the front face of dome retaining nut is approximately flush with edge of barrel.

(14) Install dome retaining nut lock screw and safety the screw with a cotter pin.

(15) Install breather tube nut, tighten and safety with a lock wire on propellers installed on engines that breathe through the propeller shaft. Make sure that plug in front of dome is tight and that lock wire is in place on propellers installed on engines that do not breathe through the propeller shaft.

(16) Make certain that barrel oil drain plug is tight and safetied.

(17) With the aid of blade beams, shift propeller into full low pitch position and check all blade angles. These angles are equal and agree with the low pitch stop setting.

(18) Check all external safety wire and cotter pins.

b. To remove propeller from shaft—

(1) Remove plug and seal in front of dome for engines which do not breathe through the propeller shaft, or breather assembly for engines which breathe through the propeller shaft.

(2) Remove safety screw, unscrew dome retaining nut, and lift off dome.

(3) Remove locking pin from propeller retaining nut and unscrew valve assembly.

(4) Loosen retaining nut and remove propeller.

42. Lubrication.—This propeller requires no internal lubrication as all parts operate in oil supplied by the engine. The blades and hub are coated with clean engine oil as outlined in section IX.

43. Propeller controls.—a. The propeller control (fig. 26) is a self-contained governor suitable for mounting on the special built-in pad on the nose of the engine. The unit consists of the same gear type booster pump which boosts the engine oil from engine pressure to higher pressures required to operate the propeller pitch changing mechanism. A pilot valve controls the flow of oil to and from the propeller. It is actuated by the same spring balanced flyballs used in the control for the counterweight type propeller. The minimum limit of the governing range of the unit is set by the low r. p. m.

adjusting screw in the speed adjusting rack. A relief valve plunger permits the force of the relief valve to be supplemented by the force of engine oil pressure; thus the relief valve will operate at a pressure equal to engine oil pressure plus the spring pressure. A transfer valve in the base of the unit provides a passage through which the high pressure oil passes for feathering and unfeathering operations of the propeller. The size, weight, and general shape of the control are the same as that of the constant speed control. The method by which the oil enters and passes through the gear pump and is delivered into the hollow portion of the drive gear, is the same as the constant speed control.

b. Figure 27 shows the positions and functions of the various parts of the control during the "on speed," "underspeed," "overspeed," and "in and out" of feather conditions. The "on speed" condition (fig. 27 ③) exists when the flyball and spring forces are in balance, causing the pilot valve to close the line to the propeller and maintain a given blade angle. Both pressure and drain ports are closed during this condition. All oil from the gear pump is by-passed through the relief valve back to the inlet side of the pump. The "underspeed" condition (fig. 27 ①), exists when the speed of the flyballs has been reduced and the spring force overcomes the force of the flyballs. In this condition, the spring forces the pilot valve down. The upper land of the valve moves below the metering port in the drive gear and cuts off the high pressure oil, and the lower land moves into the recess in the gear and opens the propeller line to drain. When oil drains from the rear of the hydromatic piston, the blades assume a lower angle and permit the engine speed to return to its original value, and the flyballs and speeder spring in the control unit return to a balanced state, as shown in the "on speed" condition. In the "overspeed" condition (fig. 27 ②), the flyball speed has increased, their forces have exceeded the force of the speeder spring, and the pilot valve is raised. The upper land of the valve then opens the ports through which the high pressure oil flows and the lower land closes the drain. Since oil pressure to the rear of the piston increases the blade angle, the engine speed is reduced and the flyball spring forces return again to a balanced state as shown in the "on speed" condition. During the feathering and unfeathering operations of the propeller, high pressure oil from an auxiliary source is supplied to the propeller through a transfer valve in the base of the constant speed unit. The function of this valve is to cut off oil from the unit to the propeller and open the passages through the engine nose to the high pressure feathering oil. The valve assembly consists of a

plunger, a return spring, and a ball check. The auxiliary high pressure oil forces the plunger against the spring, as shown in figure 27 (4). When either operation is completed and pressure at the source of the auxiliary oil supply is reduced, the spring returns the ball to its seat and reopens the propeller line to governor oil. The propeller then operates as a constant speed propeller.

c. Installation of the governor and cockpit controls (fig. 28) should be in accordance with installation drawings covering the particular airplane, except that the following precautions should be taken:

(1) The controls should be checked to insure their proper functioning before installing on the engine.

(2) To install the governor, remove cover from surface on which governor is to be mounted. Set governor in position, checking fit of governor circular lining boss.

(3) The governor securing nuts should then be placed on the mounting studs and run down finger tight. Remove governor head and check backlash and freedom of movement while tightening governor securing nuts. It is essential that these nuts be tightened evenly. The securing nuts should not be drawn down excessively tight, as this may cause displacement of the gasket material in the vicinity of the mounting studs and result in warping the governor base. In some cases it has been noted that the governors are susceptible to binding after having the nuts tightened. This condition can be relieved by slacking off slightly one or more nuts. The nut or nuts causing the difficulty can be determined by trial.

(4) It is advisable, during tightening of the securing nuts, that the propeller shaft be rotated to at least three positions, checking the governor for backlash and freedom of movement at each point. The primary precaution is to make sure the governor turns freely when assembled to its drive on the engine.

(5) Connect auxiliary line and cut-out switch wires if used.

d. The governor and cockpit controls are removed as follows:

(1) Disconnect cockpit control from unit.

(2) Disconnect high pressure pipe from base of control unit. On some governors the cut-out switch is also disconnected.

(3) Remove mounting stud nuts.

(4) Remove governor. If it is necessary to temporarily remove a unit between propeller overhauls, the cockpit control should be moved to the high pitch (low r. p. m.) position and the pulley or lever shaft and should be marked in relation to cover before removal

from the control shaft. This will permit reinstallation in exactly the same position and facilitate readjustment of the control system.

44. Operation.—*a.* (1) The engine is started with the propeller control in low pitch (high r. p. m.) position. This position reduces the load or drag of the propeller and the result is easier starting and warm-up of the engine, also is normally the position of the propeller prior to stopping the engine.

(2) For take-off, climb, and flight, the operation instructions governing the engine airplane combination should be consulted for best r. p. m. position.

(3) When gliding in to land the airplane, the propeller control should be in a position to allow a lower r. p. m. than take-off r. p. m. This is a safety precaution to prevent speeding the engine beyond a safe r. p. m. in case of an emergency.

(4) Prior to stopping the engine, the propeller control should be moved to low pitch (high r. p. m.) position.

b. Feathering is accomplished by supplying oil from an independent source, not controlled by the governor, to the inboard end of the cylinder at pressures sufficient to move the cam rollers over the feathering or low mechanical portion of the cam slots under any conditions of r. p. m. and power that may be expected in flight. In some airplanes, the feathering oil pump receives its supply from the hopper tank connection in which cold or atmospheric temperature oil may be delivered, resulting in excessive pressure in the feathering oil line which will operate the pressure cut-out switch. This in turn will stop the feathering pump motor. With the motor stopped, the propeller feathering cycles is not completed. However, this can be overcome by again depressing the control switch and holding it in by hand until the feathering cycle is completed. This will require that the operator watch the propeller carefully and release the switch as soon as the propeller ceases to windmill. At any time, the automatic feathering action can be interrupted by manually pulling out the control switch to break the motor circuit. The windmilling propeller will then resume constant speed operation without further attention.

c. Unfeathering the propeller consists essentially of reversing the passages in the distributor valve in order to permit the high pressure oil from the auxiliary system to act on the outboard end of the piston while the inboard end is connected to the engine lubricating system. To unfeather, it is necessary only to depress the propeller control switch and hold it closed until the propeller is unfeathered to the desired r. p. m. (800) then promptly released.

d. In case of emergency, when it is necessary to feather the propeller in the shortest possible time (if the engine has stopped for minor cause and has been permitted to rotate due to windmilling of the propeller) the instructions given for emergency feathering should be followed. In case of practice feathering while flying, the period of time the propeller is left in the feathered condition will not exceed 15 minutes. This requirement is necessary because during the feathering operation the quantity of oil forced into the engine nose may be great enough to seep down past the piston rings of the lower cylinders into the combustion chamber, and if not removed before rotating the propeller, may result in damage to the engine. The following instructions apply when feathering the propeller in flight.

(1) *Emergency feathering.*

- (a) Close propeller feathering switch.
- (b) Close throttle.
- (c) Move mixture control to idle cut-off position (depending on type of engine and carburetor).
- (d) Turn off fuel supply.
- (e) Leave ignition switch "on" until propeller stops and then turn off.

(2) *Practice feathering.*

- (a) Close throttle.
- (b) Move mixture control into idle cut-off position.
- (c) Turn off gasoline supply to engine.
- (d) Close propeller feathering switch.
- (e) Leave ignition switch "on" until propeller stops, then turn switch off.

(3) *Unfeathering (return from feathering).*

- (a) Turn ignition switch "on" with throttle closed.
- (b) Set propeller cockpit control to the minimum r. p. m. (high pitch) position.
- (c) Turn on fuel supply.
- (d) Close propeller control switch and keep closed until tachometer reading reaches 800 r. p. m. Then pull out switch.
- (e) Allow engine to operate at this r. p. m. until required temperature is obtained. Then open throttle gradually, causing engine to speed up to the minimum r. p. m. or the speed for which governor is set.

(f) Adjust mixture.

- (g) Adjust throttle and governor setting to desired power and engine r. p. m., and synchronize.

e. In connection with the feathering and unfeathering operation of the propeller, the following points will be carefully noted:

(1) In flight, the propeller begins to windmill and crank the engine as soon as it starts to unfeather. The engine speed increases rapidly as power is applied and automatic unfeathering proceeds.

(2) It is important when unfeathering a propeller after the engine has cooled, to idle at slow speed until the engine is thoroughly warmed up before bringing it up to speed, otherwise serious damage may result due to poor lubrication. The windmilling action of unfeathering is a very powerful cranking force and will easily overspeed the engine beyond safe idling speed unless care is taken to stop unfeathering while the propeller is still at very high angle.

(3) After unfeathering to about 800 r. p. m. at an air speed of approximately 125 m. p. h., the engine may be permitted to warm up as long as desired without tendency to speed up. It is only necessary to open the throttle to cause the propeller to shift to a lower angle when the governor takes charge.

(4) If the engine idling speed becomes excessive for warm-up purposes, the speed is reduced by closing the propeller control switch to partially feather again. The switch is released when the desired r. p. m. is reached.

(5) The operation of the propeller distributor valve is such that the blades cannot be unfeathered by means of the auxiliary high pressure oil until they have first reached the full-feathered position. Thus, after an interruption in the flow of high pressure oil, a reapplication of the pressure will cause the propeller to move toward the feathered position regardless of whether its direction of motion, prior to the pressure interruption, was toward feathering or toward unfeathering.

(6) From the above it is evident that should the feathering switch be closed (or the high pressure oil applied) inadvertently, the feathering action can be stopped and the propeller returned to constant-speed control by manually reopening the control switch (or discontinuing the high pressure supply). If accidental operation of the feathering control has resulted in complete (or nearly complete) feathering the propeller is unfeathered in the normal manner.

(7) Oil pressure is not required to hold the blades in the full-feathered position. Once the blades have been feathered and rotation stopped, torque producing aerodynamic forces are in equilibrium and there is no tendency for the propeller to rotate.

45. Inspection and inspection maintenance.—a. When performing a preflight inspection, the range of operation of the Hamilton standard hydromatic propeller is checked as follows:

(1) After completing the engine warm-up, open throttle to some intermediate engine speed, for example 1,800 r. p. m.

(2) Move propeller control to high pitch (low r. p. m.) position and note decrease in engine r. p. m.

(3) Without disturbing throttle setting, move propeller control to low pitch (high r. p. m.) position and note increase in engine r. p. m. If both increase and decrease in engine r. p. m. is indicated on the tachometer, the propeller is functioning correctly.

b. An inspection is made after initial installation and before each flight for oil leaks. Between the blades and hub, around the base of dome, and between the two halves of the hub oil leaks are most likely to occur. If a check on the tightness of bolts and nuts fails to correct the condition, the services of a trained propeller mechanic should be obtained. Any leak should be corrected before flight.

c. The markings on both blade and hub are inspected for deterioration. In event the markings or protective coating are not in good condition, the propeller is removed from the crankshaft and markings or protective coating renewed with the propeller on the balancing stand. This is accomplished by a qualified propeller mechanic.

d. At the specified periodic inspection, the retaining nut of the hydromatic propeller is checked as follows:

(1) Remove lock ring and breather cup from front of dome. (This applies to installations on engines which breathe through the propeller shaft.)

(2) Remove lock screw from dome retaining nut and unscrew nut. This nut is attached to the dome and acts as a puller when the nut is unscrewed.

(3) Remove dome assembly.

(4) Remove lock ring from propeller retaining nut.

(5) Check retaining nut for looseness by using tubular wrench together with composite wrench and a bar approximately 3 feet long. Apply a force of approximately 180 pounds at end of bar, and while this force is being maintained, rap bar close to the wrench with a hammer weighing about 2½ pounds. (It is not necessary to remove the valve assembly but care should be taken to prevent damage to it by the wrench.)

(6) Install lock ring with pin through retaining nut slot, propeller shaft hole, and into valve housing slot. Snap wire into position in groove provided for it in retaining nut.

(7) Install dome assembly.

(8) Install dome retaining nut lock screw and safety the screw with a cotter pin.

(9) Install breather cap and safety it with locking ring provided.

e. All controls, switches, pumps, etc. are inspected for security of mounting. All external braces and fittings are inspected for cracks, elongated holes, and for other defects. Any defect noted is corrected before flight.

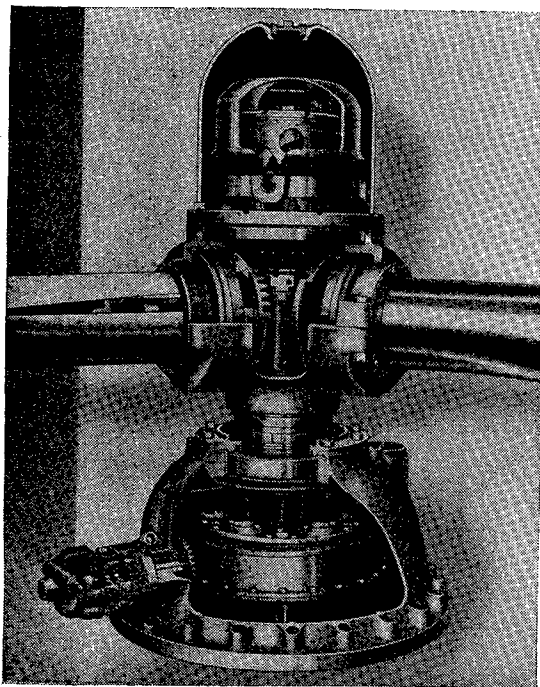


FIGURE 23.—Cut-away of the Hamilton standard hydromatic propeller.

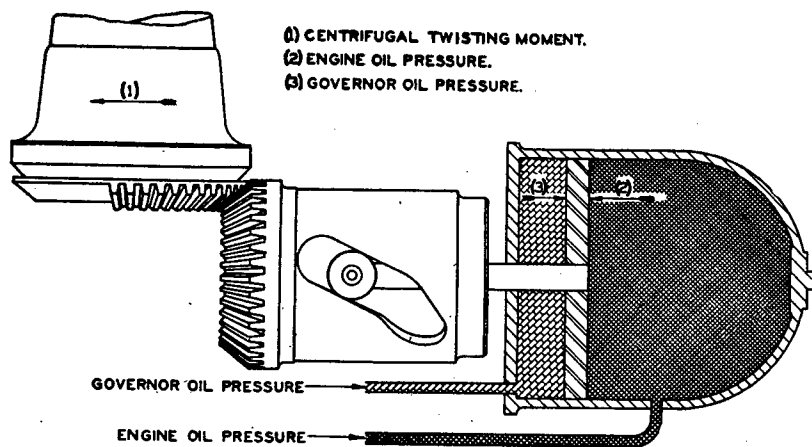


FIGURE 24.—Propeller control force.

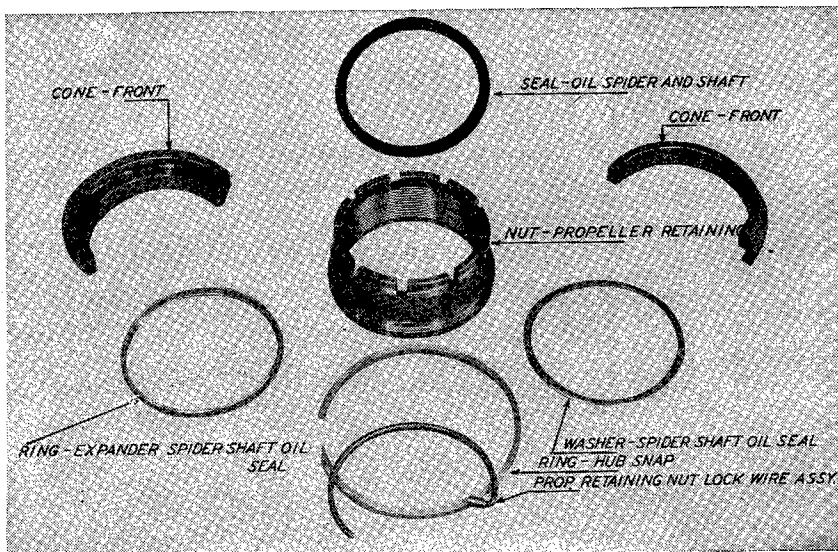


FIGURE 25.—Retaining nut and attaching parts.

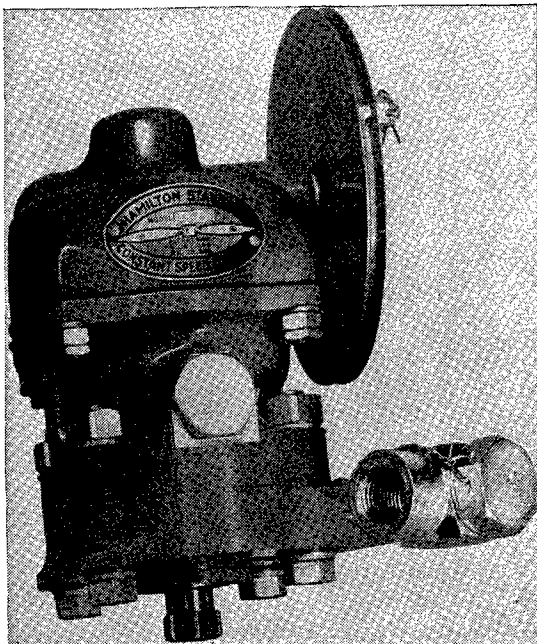
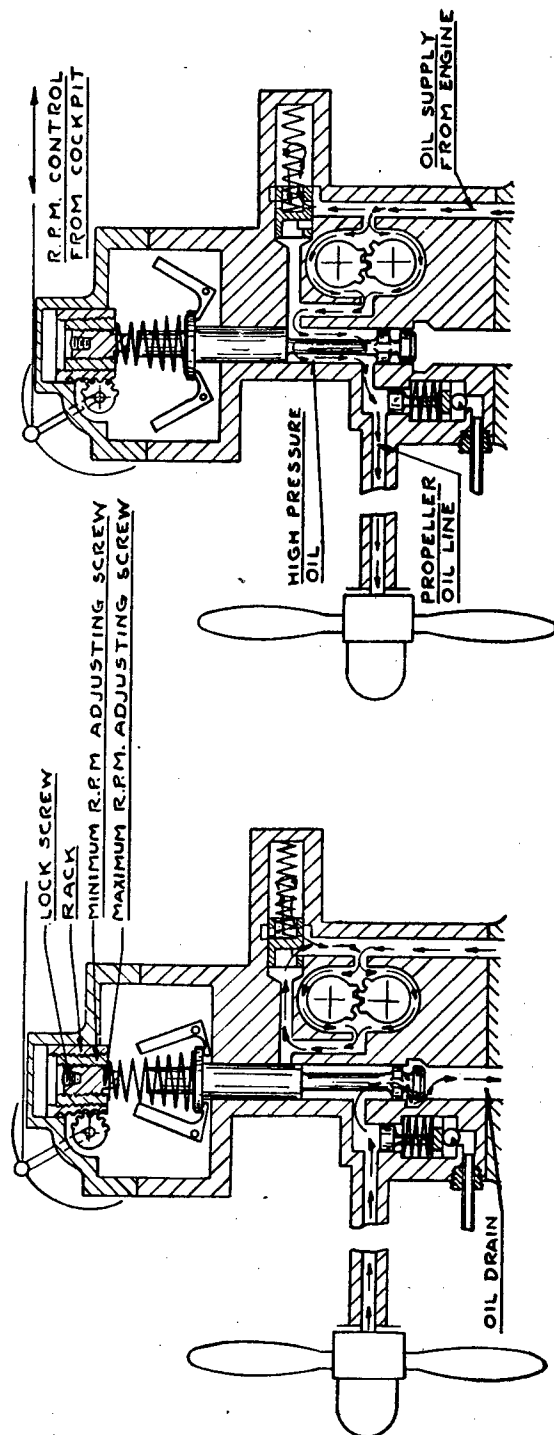
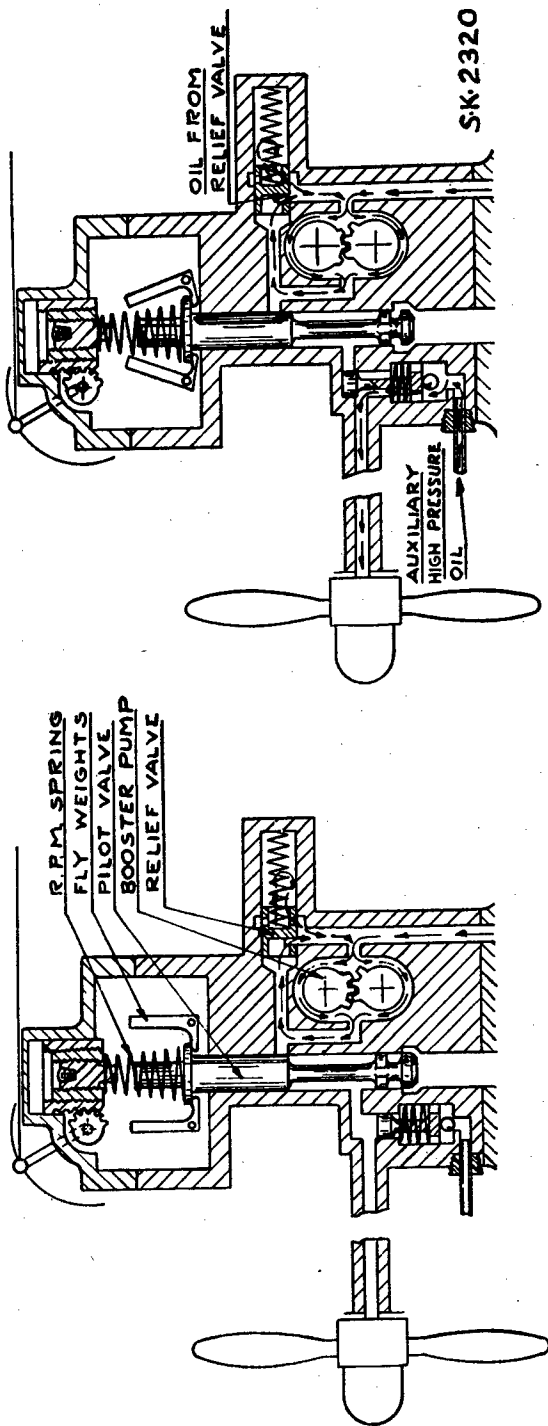


FIGURE 26.—Governor assembly.



② "Overspeed." High pressure oil enters propeller to increase pitch.

① "Underspeed." Oil drains from propeller to decrease pitch.



② "On speed." Pilot valve closes propeller line to maintain pitch. ③ "In and out" of feather position. Oil from auxiliary source direct to propeller.

FIGURE 27.—Operation of the governor (schematic view).

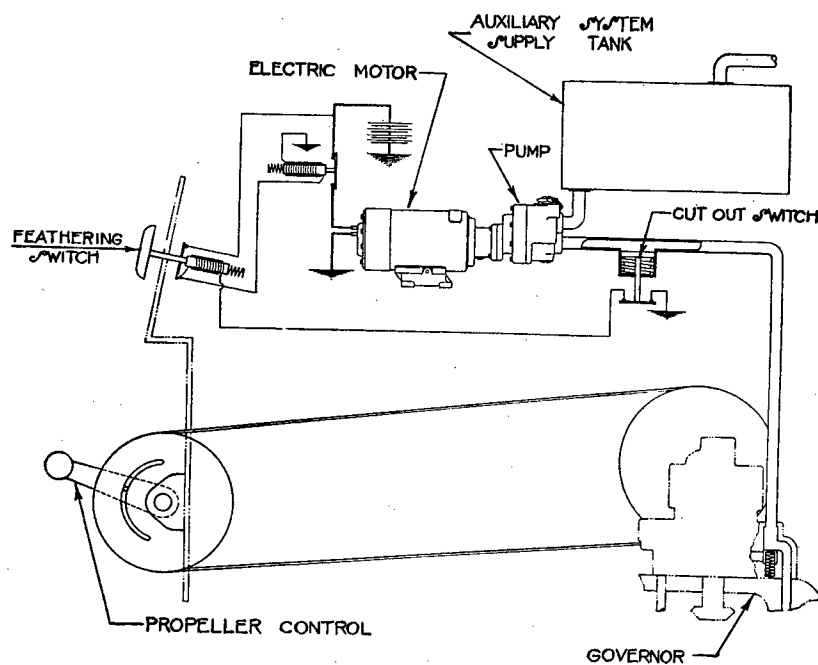


FIGURE 28.—Auxiliary control system.

SECTION VIII

PROPELLER ANTI-ICER EQUIPMENT

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46. Performance.—*a.* The Eclipse pump (fig. 29) is designed to deliver a minimum of 4 quarts and a maximum of 10 quarts of anti-icer solution per hour to the propeller hub, pilot's windshield, or carburetor venturi, depending upon the particular installation. Each pump is designed for use in conjunction with two propellers. The pump motor is designed to operate on 12 volts, d. c., with a maximum current consumption of 2 amperes when operating at maximum capacity.

b. The Pesco pump (fig. 30) is used for the same purpose as the Eclipse pump. It is manufactured in two types; one operates on 12 volts, d. c., and delivers 50 cc. (minimum) to 170 cc. (maximum)

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per minute. The other operates on 24 volts, d. c., and delivers 60 cc. (minimum) to 175 cc. (maximum) per minute.

c. A control rheostat is designed for use in conjunction with both the Eclipse and Pesco type pumps as a means of remotely controlling the output of the pumps to the required value.

47. Description.—*a.* The Eclipse propeller anti-icer pump is an electrically driven dual diaphragm pump, suitable for operation from a 12-volt battery source, and designed to deliver a metered supply of alcohol-glycerine solution to a slinger ring located at the propeller hub. The dual pump consists of two fabric diaphragms actuated by a double cam driven by an electric motor through a worm reduction. Steel ball check valves are used in the inlet and outlet passages of the pump. All steel and bronze parts including valve springs are cadmium plated as protection against corrosion. The main pump body and lower housing are made from magnesium alloy, and the pump head is made from aluminum alloy. An oil reservoir in the pump base provides a self-containing automatic method of lubrication. Oil is distributed to all moving parts, with the exception of the motor bearings, by means of the underside of the pump diaphragms which are connected with the oil reservoir.

b. The Pesco propeller anti-icer pump is a combination of two small gear type pumps contained in a bronze housing and driven by a series wound direct current motor through a 10:1 reduction gear system. The purpose of the two sets of gears is to provide independent discharge from two different outlet ports for twin-engine installation.

c. A control rheostat suitable for mounting on the instrument panel is provided with each pump. The unit consists of a wire-wound variable resistance, assembled in a cast alloy housing. The shaft of the resistor, which is rotated, extends through the front of the housing and is provided with a Bakelite knob to facilitate operation. A plate is mounted on the front of the housing and is suitably marked to indicate the proper direction of the knob to increase and decrease the output of the pump as desired.

48. Installation.—Before installing the propeller anti-icing pump, refer to the standard drawing for the airplane and the Air Corps Technical Orders pertaining to the type pump and the airplane involved. The Eclipse type anti-icer pump should be primed when it is installed and whenever the tank runs dry. To prime with the electric motor running, back off the two inlet valve plugs approximately three turns. Leave pump running until all air is expelled from the system and a steady flow of liquid is obtained,

then tighten the valve plugs. It is never necessary to prime the Pesco type pump. Figure 31 shows a typical installation.

49. Operation.—The operation of the propeller anti-icer pump is automatic upon operation of the control rheostat. When the control knob is turned all the way to the left, facing the knob, the circuit is open and the motor is inoperative. To place unit in operation, turn knob to the right to maximum output position for 30 seconds, then to the left until desired output is obtained. To increase output, turn knob to the right; to decrease output, turn to the left. The operating speed of each pump is varied in order to obtain the correct output.

50. Rubber-covered propeller spinners.—To prevent the building up of a heavy coating of ice on the front part of the propeller hub, a special de-icing spinner is attached to the front of the propeller. It is usually spun from aluminum. This insures a perfectly concentric and lightweight part. Inasmuch as it rotates with the propeller, it is manufactured as a balanced unit, and when possible after its installation, the propeller is rechecked for balance. A resilient covering of rubber is cemented to the outside of the spinner. When this rubber is coated with a special de-icer oil or castor oil, the surface adhesion is so lowered that centrifugal forces from the rotation are sufficient to fling off any particles as they form. After flight and during storage, the spinner is treated with a preservative to retard the checking of the rubber.

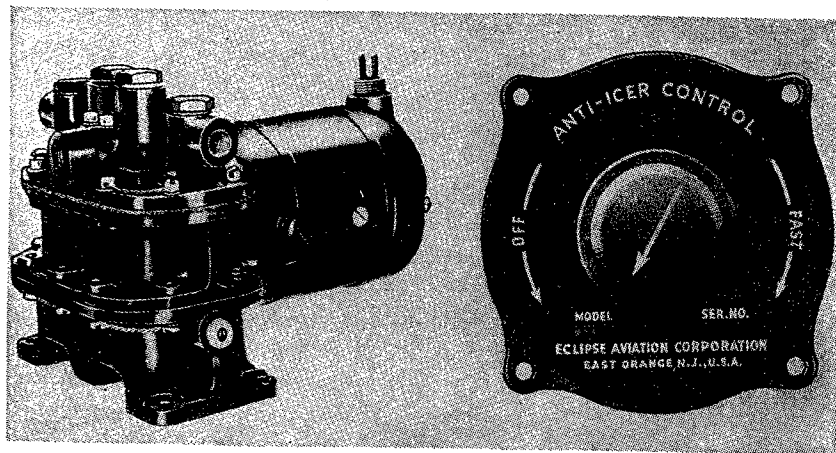


FIGURE 29.—Anti-icer pump and control (Eclipse).

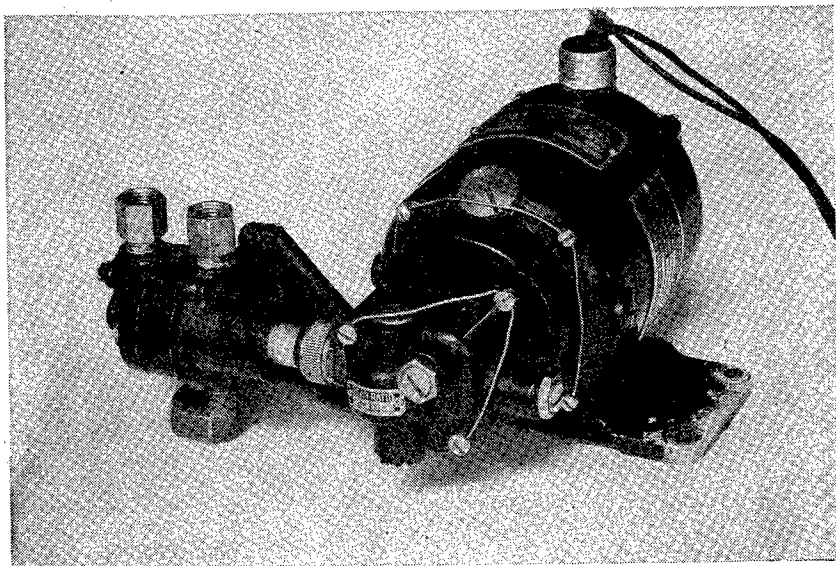


FIGURE 30.—Anti-icer pump (Pesco).

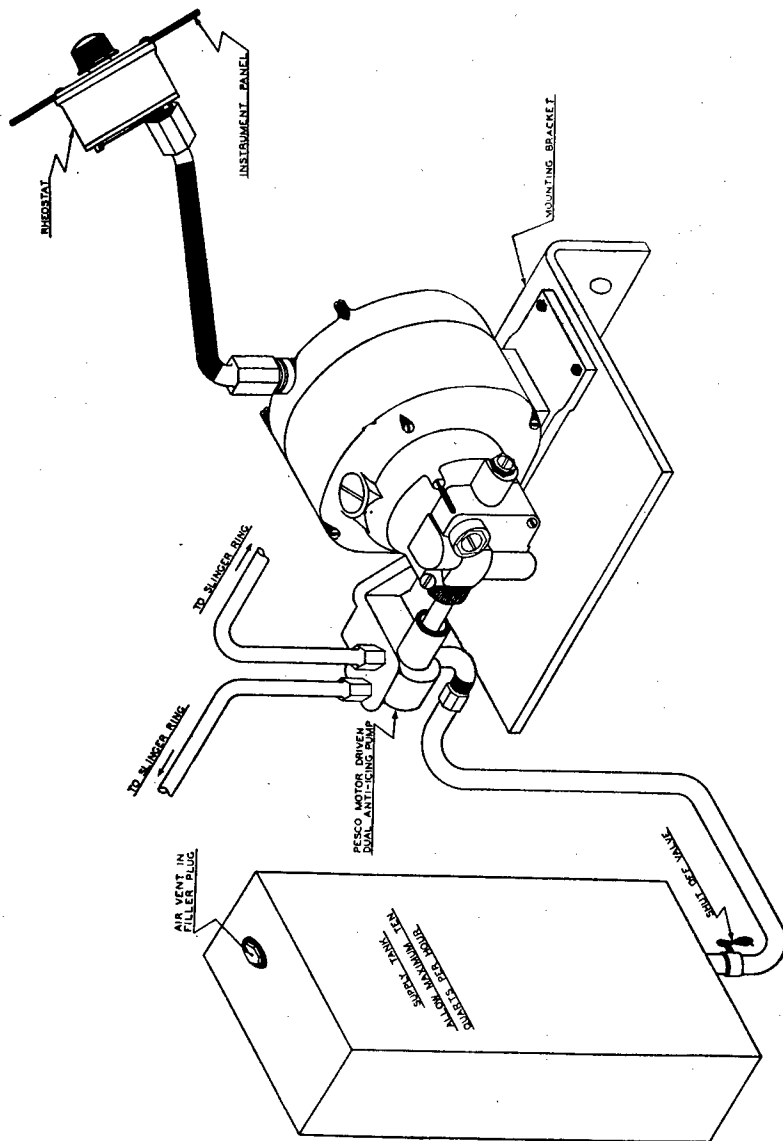


FIGURE 31.—Typical anti-icer installation (Pesco).

SECTION IX

GENERAL MAINTENANCE AND REPAIR

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51. General.—Any unit equipped to perform repair and maintenance may do so provided such repair or maintenance conforms to existing regulations. Unless otherwise specified, the instructions outlined in the paragraphs below are applicable to all propellers.

52. Cleaning for inspection.—*a.* All foreign substance is removed from the surfaces involved before an inspection is made.

b. Steel hubs are cleaned with soap and water, or with gasoline or kerosene, and suitable cloth or brushes. Tools and abrasives that will scratch or otherwise damage the plating should not be used.

c. Warm water and soap, gasoline or kerosene, and suitable brushes or cloth as may be available and practicable are used for the cleaning of aluminum alloy blades. Except in the case of etching and repair, scrapers, power buffers, steel wool, steel brushes, and any other tool or substance that will scratch the blade are not used. In special cases where polish is desired, a good grade of metal polish may be used, provided that on completion of the polishing all traces of the polish are removed. This is necessary to prevent corrosion by acid contained in the metal polish.

d. All cleaning substances are immediately removed upon completion of the cleaning of any propeller or part. Soap in any form is

removed by thoroughly rinsing with fresh water after which all surfaces are dried and coated with oil.

e. Caustic material is not used on any propeller. The removal of enamel, varnish, etc., from all propellers is accomplished by the use of suitable solvents such as approved paint and varnish remover.

53. Removal of salt.—All traces of salt on the propeller are removed by flushing with fresh water soon after being subjected to salt water. All parts are then dried and coated with clean engine oil.

54. Coating propeller blades and hub with oil.—Immediately after completing inspection and other work and following each cleaning and etching, all uncoiled surfaces of the blades and hub are coated with clean engine oil. Upon completion of each day's flying, all outside surfaces of propellers are coated with clean engine oil. Exposed surfaces of blades and hubs installed, but not in actual service, are coated with clean engine oil as often as necessary to prevent corrosion. Coating of propeller blades and hub with engine oil serves a dual purpose. The oil protects the exposed surfaces of the propeller from rust and corrosion and also seeps into a crack that might appear in the blade or hub, making the otherwise obscure crack stand out.

55. Local etching.—*a.* The purpose of local etching is to determine whether visible lines and other marks within small areas of the blade surfaces are actually cracks instead of slight scratches; to determine with a minimum removal of metal when shallow cracks have been removed; and to expose cracks that are not apparent without etching. It provides a simple means for accomplishing this work without removing or disassembling the propeller.

b. (1) The caustic soda solution used in local etching is prepared locally by adding to the required quantity of water as much commercial caustic soda as the water will dissolve. The quantity of the solution will depend on the amount of etching to be done. The caustic soda is used to remove the necessary amount of metal.

(2) The acid solution for local etching is prepared locally with one part of commercial nitric acid to each five parts of water used. The acid is used to remove the dark corrosion that results from immersion in the caustic soda solution.

(3) Glass or earthenware containers are used for the solutions.

c. Local etching is accomplished as follows:

(1) With No. 00 sandpaper, clean and smooth off the area containing the apparent defect. With a small swab or stick, apply to the suspected area a small quantity of the caustic soda solution.

(2) After the area is well darkened, thoroughly wipe it off with a clean cloth dampened with clean water. Too much water may remove the solution from a defect and thereby spoil the check.

(3) If a crack or other defect extending into the metal exists, it will appear as a dark line or other mark, and with the use of a magnifying glass, small bubbles may be seen forming in the dark line or mark.

(4) Several applications of the caustic solution may be necessary to determine when all the shallow cracks and doubled back edges of metal have been removed. However, immediately upon completion of the final checks, all traces of the caustic soda are removed with the nitric acid solution, which in turn, will be thoroughly rinsed off with fresh clean water. The blade is dried and coated with clean engine oil.

NOTE.—General etching is only performed at the control depot.

56. Markings.—*a.* Between the 18- and 24-inch station on the cambered side, each detachable metal blade bears markings as follows:

- (1) Air Corps serial number.
- (2) Part number.
- (3) Blade angle setting. This setting is the blade angle at the 42-inch station and is measured with the protractor. On all controllable propellers, the index setting (when applicable), maximum angle, and minimum angle are considered part of the blade angle setting and should be marked on the blade.

(4) Date of installation. The date of installation is omitted on propellers whose overhaul period is set by the number of flying hours or at engine change. The date of installation is preceded by the letter "I".

b. The foregoing data are painted or stenciled on the blade with black enamel or stamped with a rubber stamp and printer's ink. In no instance will such markings be indented or cut into the metal. The markings will be protected with a coat of spar varnish or clear lacquer.

c. No decorative markings or coatings should be placed on blades or hub. Manufacturers' trade-marks are not considered decorative.

d. Reworked or modified hubs are stamped with a letter "M" following the part number stamped on the halves of the hub. These hubs have been so modified that they are to be used on short splined crankshafts.

57. Coating with antiglare.—To prevent glare, the face side of the propeller blades may be coated with antiglare. This coating extends from the 24-inch station to the tip. Maroon lacquer is preferred, but is not available, maroon enamel may be used. After the coatings have dried, the propeller is checked for balance. Any un-

balanced condition caused by the application of the finishes is eliminated by adding lacquer or enamel to the coated surface of the light blade. At no time will the antiglare be renewed or applied with the propeller installed on an airplane.

58. Eliminating bottoming of front cones.—*a.* Due to manufacturing tolerances of certain crankshaft dimensions, the front cones occasionally bottom against the outer ends of the splines and therefore cannot be tightened against the cone seats in the hub. In other words, such splines hold the cones so far apart that the hubs cannot be tightened on the shafts regardless of how tightly the propeller-retaining nut or piston is drawn up.

b. A check for possible bottoming of front cones is made whenever a splined hub propeller is installed. This check is made as follows:

(1) Apply a thin coating of Prussian blue to inner end face of front cone.

(2) Assemble front cone on retaining nut or piston and firmly tighten parts.

(3) Unscrew retaining device and see if the blue has been transferred to ends of splines of crankshaft.

(4) If no such transfer is indicated, clean off the Prussian blue, reassemble, tighten, and secure parts.

(5) If blue is transferred to the ends of the splines, the bottoming is corrected by the use of a steel spacer of the required thickness and diameter which is installed behind the rear cone. These spacers are made locally and are $\frac{1}{8}$ inch in thickness. A second check is made after installation of the $\frac{1}{8}$ -inch spacer, and if bottoming still occurs, a thorough check is made of the hub, shaft end, and all attaching parts for excessive wear or any other conditions likely to cause the misfitting. Any worn or damaged part will be replaced.

NOTE.—Some crankshafts have tapered seats for the rear cones. Such rear cones cannot be moved forward by spacers. If the front cone bottoms on splines of these shafts, the rear cones will be replaced.

59. Repair of minor defects in aluminum alloy blades.—*a.* To avoid dressing off an excess amount of metal when repairing a minor defect, it is advisable to locally etch the repair at intervals. Suitable sandpaper or fine-cut files are used for removing the necessary amount of metal, after which in each case, the surface involved is smoothly finished with No. 00 sandpaper. Each blade from which any appreciable amount of metal has been removed is balanced before it is used. Cracks, cuts, scars, scratches, nicks, etc., can be removed or otherwise treated as explained and shown in figure 32, provided

their removal or treatment does not materially weaken the blade, reduce its weight, or impair its performance.

b. The metal around longitudinal surface cracks, narrow cuts, and shallow scratches is removed to form shallow saucer-shaped depressions, as shown in figure 32. Blades requiring the removal of metal forming a finished depression more than $\frac{3}{32}$ inch in depth at its deepest point, $\frac{9}{32}$ inch in width overall, and $\frac{3}{4}$ inch in length at the tip portion and extending approximately 10 inches from the tip; or $\frac{1}{8}$ inch in depth at its deepest point, $\frac{3}{8}$ inch in width overall, and 1 inch in length overall at surfaces other than the tip portion are condemned.

c. The metal at the edges of wide scars, cuts, scratches, nicks, etc., is rounded off and the surfaces within the edges are smoothed out as shown in figure 32. Blades that require the removal of metal to a depth of more than $\frac{3}{32}$ inch and a length of more than $\frac{9}{16}$ inch at the tip portion at the area extending approximately 10 inches from the tip and $\frac{1}{8}$ inch in depth, and a length of more than $\frac{3}{4}$ inch overall at areas other than the tip portion are condemned.

d. Blades that have the leading edge pitted from normal wear in the service may be reworked by removing sufficient material to eliminate the defects. In this case the metal is removed by starting approximately at the thickest section and working forward over the nose camber so that the contour of the reworked portion will remain substantially the same, avoiding abrupt change in section or blunt edges. With the exception of cracks, it is not necessary to completely remove or "saucer out" all of a deep defect. Properly rounding off the edges and smoothing out the surface within the edges is sufficient, as it is essential that no unnecessary amount of metal be removed. More than one defect falling within the above limitations is not sufficient cause alone for rejection of the blade. A reasonable number of such defects per blade is not necessarily dangerous, if within the limits specified, unless their location with respect to each other is such as to form a continuous line of defects that would materially weaken the blade.

60. Repair of minor defects in hollow steel blades.—*a.* No attempt is made to repair a crack, bend, or bullet hole, without specific authority and detailed instructions from the chief of the matériel division.

b. The raised edges of scars, cuts, scratches, etc., are polished out by handstoning. The amount of metal removed should be as small as possible so that there will be no abrupt change of section that would cause a stress concentration at any point. Under no circumstances

will any other metal be removed nor will other tools be used for this purpose.

c. Small shallow dents located on the leading or trailing edge or near the tip of the propeller blade are of no consequence, and therefore do not require repairs.

61. Noninterchangeability of front cone halves.—Due to permissible manufacturing tolerances, the halves of propeller hub front cones are not interchangeable. When a serviceable front cone is turned into stock, the two halves will be taped together. When one half is found unserviceable, the other half is disposed of. The two halves of a front cone, before having been used, are held together by a thin section of metal, and it will be necessary to "break" the two halves before installing. After separating the two halves of such cones, all resultant fins and rough edges are removed and sharp edges where the cones are cut through are rounded off. This work is accomplished by careful handstoning.

62. Checking a propeller for track in the field.—There are several methods for checking a propeller for track in the field; none of them, however, can be considered as an accurate check. The preferred method is to attach a fixed point to some part of the airplane so that it touches the blade face near the extreme tip of the blade. Rotate propeller until the next blade is in the same position and note distance between blade face and fixed point. Repeat the operation for each of the other blades. This method eliminates blocking the wheels of the airplane and any movement of the airplane will not change the position of the fixed point relative to the blade face. Figure 33 shows this method of checking for track with the propeller installed on the airplane.

63. Emergency installation of a ground adjustable propeller.—When it is necessary to ship a propeller for installation on an airplane to a point where balancing facilities are not available, and the weight and size of the propeller make it impracticable to ship it assembled, the procedure below is followed:

a. The propeller is completely assembled, tracked, blade angle set, and the propeller balanced in the Air Base shops. Each blade, hub barrel, and clamp ring are numbered as shown in figure 34. A small area is painted on each blade adjacent to the hub extending across the end of the hub barrel and onto the clamp ring. When the paint has dried, a reference line is scribed so that the exact position of each blade in the hub and also that of the clamp ring will be visibly registered. The propeller is then disassembled and packed for shipment.

b. Upon receipt of the propeller at its destination, assemble the blades in the hub, being careful to assemble each blade and clamp ring

to the correspondingly numbered hub barrel. After assembling the propeller, proceed with the installation as follows:

(1) Start hub on engine shaft. If the hub binds when partly on the shaft, it may be necessary to loosen the clamp rings and shift the front half of the hub until it also slides onto the shaft.

(2) Without tightening the clamp rings, draw hub retaining nut up snugly but not tightly.

(3) Turn propeller until one blade is vertically downward. Tap shank of blade with a rawhide mallet while pulling down on the blade. Aline scribed lines marked on blade, hub, and clamp ring. Tighten clamp ring and safety the ring clamp nut. Repeat for each remaining blade.

(4) Check all blades, clamp rings, and hub barrel numbers for correct assembly, and check alinement of scribed marks.

(5) Tighten and safety the retaining nut.

64. Preparation of crankshaft for installation.—Before installing a propeller on a splined crankshaft, the following should be accomplished:

a. Remove all grease, dirt, and foreign matter with some approved cleaning fluid.

b. Inspect threads of crankshaft for corrosion, damaged threads and general condition, and thoroughly clean. Coat threads with thread lubricant.

c. Inspect splines of crankshaft for corrosion, burs, raised points and other damage, and remove same with crocus cloth and by careful handstoning. Coat splines with clean engine oil. The use of cup grease is prohibited.

d. Inspect all attaching parts such as rear cones and spacers, and give them a light coat of engine oil before installing them on the shaft. Determine if parts bear correct part number for the assembly.

65. Checking hub for looseness on crankshaft.—The following procedure is recommended in making this check:

a. Use a stand or platform to elevate the mechanic to correct working height.

b. Grasp propeller with the hands near blade butts; attempt to move propeller fore and aft on shaft by pulling and pushing on hub.

c. Any movement of the hub on the shaft is investigated and condition corrected before flight. Allowable motion in geared engine reduction drives is considered when making this check.

66. Checking blades for looseness in hub.—When checking the blades for looseness in the hub the following procedure is recommended:

a. Turn blade to be checked to correct working height.

b. Place one hand on leading edge (near 42-inch station) the other on trailing edge. Attempt to turn or twist blade in hub. Unless the propeller is assembled with a certain amount of backlash in the blades there is no movement of the blade in the hub. As in the case of some controllable propeller, backlash will be found in the blades. This might be construed as a loose blade. When this movement becomes excessive, the cause is ascertained and corrected before flight.

67. Checking blade angles with propeller installed.—a. (1) The universal propeller protractor (fig. 35) provides a means by which blade angles can be checked with the propeller on a balancing stand or, if installed, without removing the propeller from the engine. When using this protractor, the propeller is turned so that the blade to be checked is always in a horizontal position with the leading edge up. The checking edge of the protractor is always used against the face or flat side of the blade.

(2) Checking the blade angle is simply a determination of how much the flat side of the blade slants from the plane of rotation. The first operation is to fix a point that, for checking purposes, represents that plane. This point is the zero of the vernier scale and is fixed by placing the protractor vertically against the end of the hub nut or any other convenient surface known to lie in the plane of propeller rotation with the angle of the blade. This, when the check is completed, is indicated by the number of whole degrees and tenths of a degree between the zero of the vernier scale and the zero of the degree scale, after the latter has been adjusted to the spirit level with the protractor against the flat side of the propeller blade.

(3) Ten points of the vernier scale are equal to nine points of the degree scale. The graduations of the vernier scale represent tenths of a degree, while those of the degree scale represent whole degrees. The number of tenths of a degree in the blade angle are determined by the number of vernier scale spaces between the zero of the vernier scale and the vernier scale graduation line that is the nearest to perfect alinement with a degree scale graduation line. This reading must always be made on the vernier in the same direction from the vernier zero that the degree scale has been moved.

b. The following are the operations for checking and setting blade angles when the propeller is on the engine:

(1) With a lead pencil, mark on the face of each blade to be checked the blade angle station specified for the particular propeller.

(2) Turn propeller until the first blade to be checked is in the position described in a above.

(3) Swing corner spirit level out as far as it will go from face of protractor.

(4) By turning disc adjuster, align zeros of both scales and lock disc to the ring. This lock is a pin that is held engaged by a spring. It is pulled outward and turned 90° to hold it in the released position.

(5) Release ring-to-frame lock, and by turning ring adjuster, place both zeros to the top as shown in figure 35. This lock is a right-hand screw with a thumb nut.

(6) While holding protractor (by the handle with curved edge up) in the left hand, place forward vertical edge across outer end of propeller hub retaining nut or any suitable propeller hub flat surface that is in the plane of propeller rotation (right angle to crankshaft centerline). Then, keeping protractor vertical by means of corner spirit level, turn ring adjuster until center spirit level is horizontal. This sets the zero of the vernier scale at point representing the plane of the propeller rotation.

(7) Lock ring to frame.

(8) Hold protractor (by the handle with curved edge up) in the right hand, release disc-to-ring lock and place forward vertical edge (edge opposite the one first used) against blade at station specified for the particular propeller. Keep protractor vertical by means of corner spirit level and turn disc adjuster until center spirit level is horizontal. By this adjustment, the number of degrees and tenths of a degree between the two zeros indicate the blade angle.

(9) If necessary, make required adjustment of blade and lock it in that position.

(10) Repeat these operations for each of the remaining blades to be checked.

68. Preparation for lubrication.—*a.* Procure specified lubricant for the particular propeller assembly.

b. Thoroughly clean grease gun with gasoline or some approved cleaning fluid. In event the grease gun is partially filled with lubricant of an unknown kind, it should be emptied and filled with the specified grease.

c. Inspect condition of plunger gaskets used on a hand type zerk gun.

d. Adjust power grease gun to cut-out at specified pressure.

e. Fill grease gun with lubricant.

f. Test gun and extension (if used) to determine if both are functioning properly.

69. Disposition of attaching parts.—Common hub attaching parts (nuts, cones, snap ring, etc.) that are required when a controllable propeller is installed are obtained from stock. Special attaching parts which are not common to all types of propellers are furnished with each propeller. When a controllable propeller is removed, the attaching parts are also removed; the special parts remain with the propeller and all common parts are returned to stock.

70. Special inspection.—*a.* As soon as possible after a propeller strikes or is struck by any object, the propeller is carefully examined for possible damage. On the completion of each flight during which bullets pass through the propeller rack, an examination for possible bullet damage is made. A propeller involved in an accident is not used before it is first disassembled and the parts carefully inspected for damage and misalignment. All steel parts are magna-fluxed. The aluminum alloy blades, if otherwise serviceable, will be given a general etching.

b. If, for any reason, the propeller is removed from the shaft prior to the required overhaul inspection, the propeller hub cone seats, cones, and other attaching parts will be inspected for galling, wear, bottoming, proper fit, etc. Before reinstallation all such defects will be corrected.

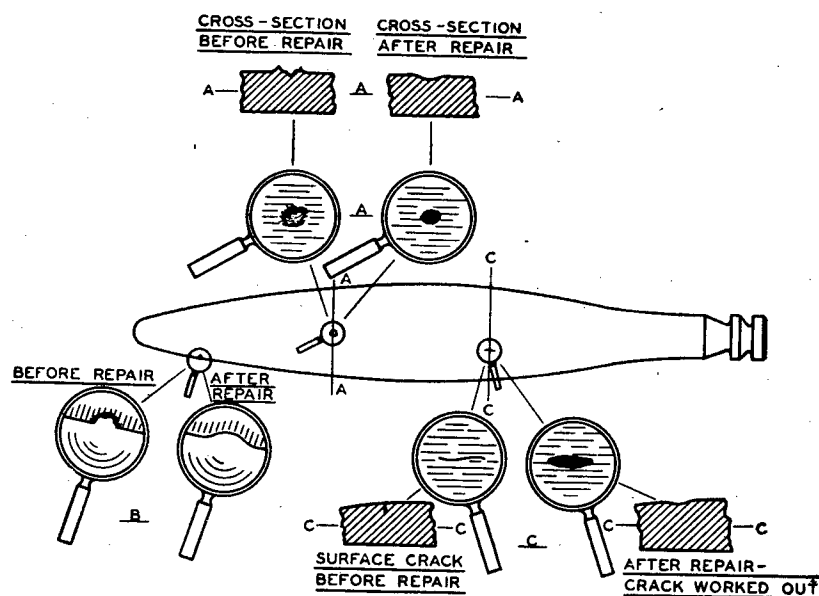


FIGURE 32.—Repair of minor defects.

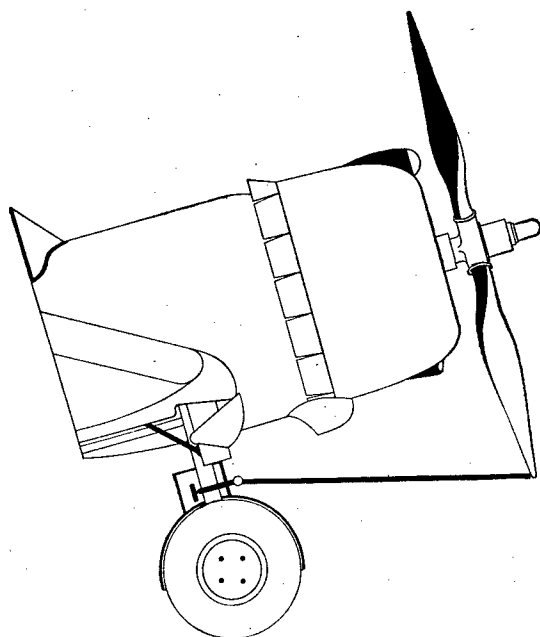


FIGURE 33.—Method of checking a propeller for track in the field.

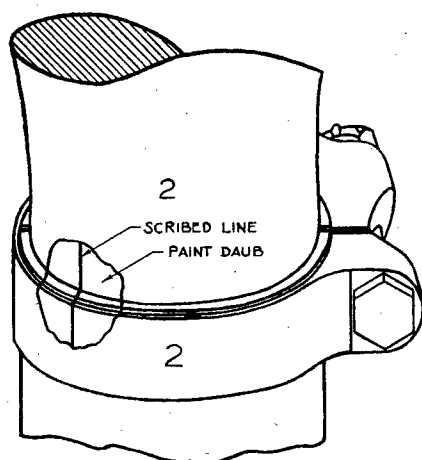


FIGURE 34.—Marking a ground adjustable propeller for installation in the field.

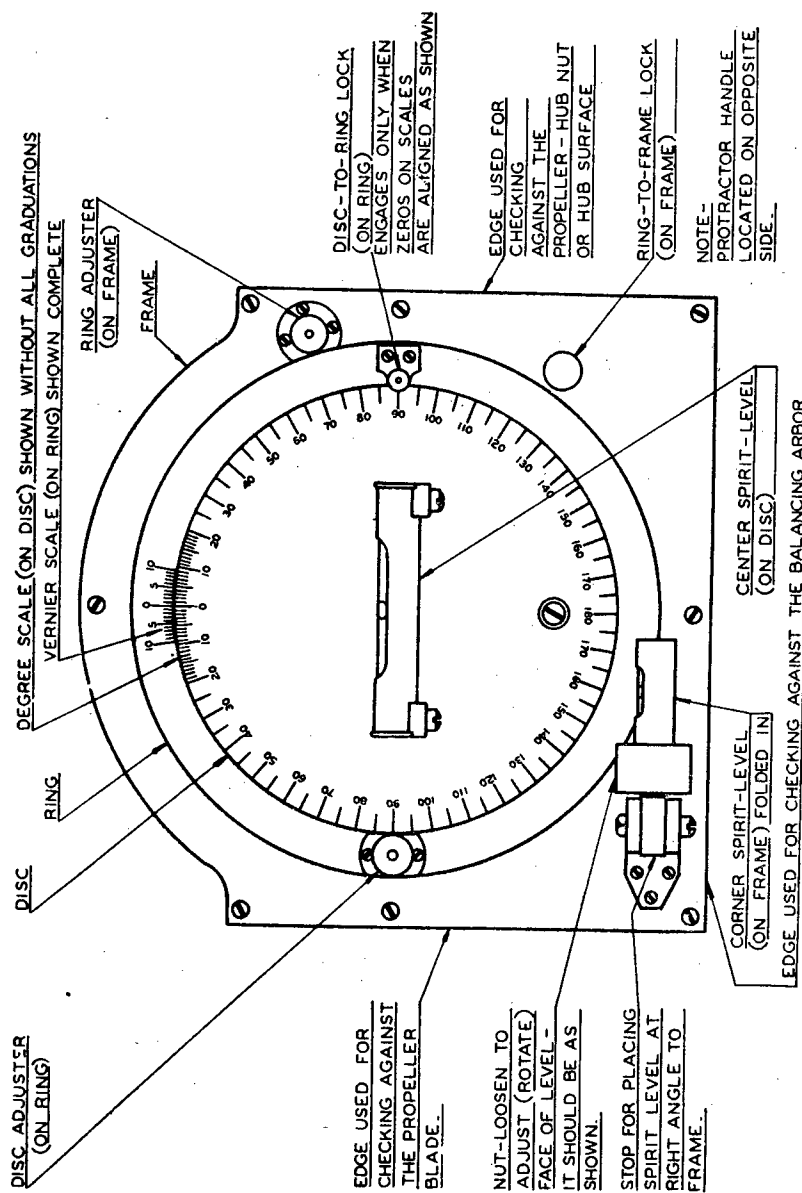


FIGURE 35.—Universal propeller protractor.

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[A. G. 062.11 (8-15-40).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

E. S. ADAMS,
*Major General,
The Adjutant General.*

TECHNICAL MANUAL

AIRCRAFT PROPELLERS

CHANGES
No. 1

WAR DEPARTMENT,
WASHINGTON, August 20, 1941.

TM 1-412, October 21, 1940, is changed as follows:

1. General.

* * * * *

b. The angle at which * * * shown in figure 3 is approached. In this case the angle of attack *E* of the propeller section *G* is **negative** and no thrust is produced. In the opposite, * * * is very low (fig. 3②).

* * * * *

[A. G. 062.11 (7-14-41).] (C 1, Aug. 20, 1941.)

19. Description.—a. The power unit consists of the motor, brake, speed reducer, and drive gear (fig. 11).

* * * * *

(3) The speed reduced * * * which is attached to the hub of the ring gear. It is adjusted to engage approximately 1° after the low limit switch **fails to operate**.

* * * * *

[A. G. 062.11 (7-14-41).] (C 1, Aug. 20, 1941.)

24. Inspection and inspection maintenance.

* * * * *

f. The brush holder is removed by disconnecting flexible conduit, removing wing nuts or clamps and disconnecting wire terminals under cover plate. The brush holder is then thoroughly **cleaned with gasoline (unleaded), kerosene, or naphtha**. Dry with compressed air. Replace all worn brushes or other damaged parts. The slip rings and the inside of brush housing are thoroughly cleaned with a cleaning fluid and dried with compressed air.

* * * * *

[A. G. 062.11 (7-14-41).] (C 1, Aug. 20, 1941.)

32. Principle of operation.—The Hamilton standard constant speed propeller * * * that the spring return is needed with 20° propellers. In low pitch (high r. p. m.), the counterweights are closer to the axis of rotation of the hub than they are in **high pitch** (low r. p. m.) position of a two-position controllable (10° pitch range). Consequently for the same * * * propeller not having a constant speed control.

[A. G. 062.11 (7-14-41).] (C 1, Aug. 20, 1941.)

39. Principle of operation.

* * * * *

e. For feathering and unfeathering, an auxiliary oil pressure supply is retained which must be independent of the engine, due to the fact that feathering causes the engine to stop running. This oil is fed into the propeller through a transfer valve in the base of the constant speed control governor. When the auxiliary oil pressure is applied, the transfer valve automatically cuts out the constant speed control and directs the oil into the propeller.

* * * * *

[A. G. 062.11 (7-14-41).] (C 1, Aug. 20, 1941.)

41. Installation and removal.—a. The provisions as outlined in section IX are followed in preparing the crankshaft for installation. The manner of installing the propeller is as follows:

* * * * *

(2) Rescinded.

* * * * *

(12) With blades still against the 90° stop pins, slide dome assembly over the end of valve assembly, making sure that the four piston rings on valve assembly enter properly into sleeve inside piston. Turn dome in a counterclockwise direction until dowel pins in barrel shelf engage with alining holes in base of dome assembly. The dome assembly is installed so that arrows stamped on dome and hub shelf are alined. The blade gears and cam gears, and also dome assembly locating screws and holes, are now in proper alinement, and the dome assembly is shoved, without turning, into the barrel. On engines which breathe through the crankshaft, make sure breather tube on front end of valve assembly is properly started into hole in front end of dome. Turning dome assembly in a clockwise direction in order to aline dowel screws and holes is to be avoided, as this will tend to move stop lugs on rotating cam away from the 90° position, thus allowing gears to mesh incorrectly.

* * * * *

(16) Rescinded.

* * * * *

b. To remove propeller from shaft—

(1) Put propeller in full feathering position.

(2) Remove plug and seal in front of dome for engines which do not breathe through the propeller shaft, or breather assembly for engine which breathes through the propeller shaft.

(3) Remove safety screw, unscrew dome retaining nut, and lift off dome.

(4) Remove retaining nut lock wire, back off retaining nut two or three turns, and then remove the distributor valve assembly, using adapter provided.

(5) Remove retaining nut from shaft.

(6) Remove propeller from shaft.

[A. G. 062.11 (7-14-41).] (C 1, Aug. 20, 1941.)

43. Propeller controls.

* * * * *

b. Figure 27 shows * * * exists when the speed of the flyballs has been reduced and the spring force overcomes the force of the flyballs. In this condition, the spring forces the pilot valve down. The upper land of the valve moves below the metering port in the drive shaft and cuts off the high pressure oil, and the lower land moves into the recess in the shaft and opens the propeller line to drain. When oil drains from the rear of the hydromatic piston, * * * then operates as a constant speed propeller.

[A. G. 062.11 (7-14-41).] (C 1, Aug. 20, 1941.)

45. Inspection and inspection maintenance.

* * * * *

b. An inspection is made after initial installation and before each flight for oil leaks. Between the blades and hub, around the base of dome, and between the two halves of the hub oil leaks are most likely to occur. To correct the condition, the services of a trained propeller mechanic should be obtained. Any leak should be corrected before flight.

* * * * *

[A. G. 062.11 (7-14-41).] (C 1, Aug. 20, 1941.)

57. Coating with antiglare.—To prevent glare, the face side of the propeller blades may be coated with antiglare. Antiglare extends from the 24-inch station to the tip of the blade, or closer to the hub on some late types of propellers. Maroon lacquer is preferred, but if not available, maroon enamel may be used. After the coatings have dried, the propeller is checked for balance. Any unbalanced condition caused by the application of the finishes is eliminated by adding lacquer or enamel to the coated surface of the light blade. At no time will the antiglare be renewed or applied with the propeller installed on an airplane.

[A. G. 062.11 (7-14-41).] (C 1, Aug. 20, 1941.)

67. Checking blade angles with propeller installed.—a. (1)
The universal * * *

* * * * *

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(3) Ten points of the vernier scale * * * that is the nearest to perfect alinement with a degree scale graduation line. This reading must always be made on the vernier in the **opposite** direction from the vernier zero that the degree scale has been moved.

* * * * *

[A. G. 062.11 (7-14-41).] (C 1, Aug. 20, 1941.)

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